Phosphorus Loading in Lake Champlain

A geographic, environmental, civic and economic investigation into its causes, effects, and prospects for the future

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led by
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Executive Summary

As any frequent visitor can see, there is something wrong with Lake Champlain. Each summer, excess amounts of phosphorus cause unsightly algal blooms that reduce the dissolved oxygen in the water and prevent sunlight from reaching other aquatic plants. This process, wherein human activity and soil erosion load water bodies with nutrients that increase plant and algal growth, is called cultural eutrophication. The resulting blooms of blue-green algae (cyanobacteria) release noxious odors, visually degrade Lake Champlain, and pose health risks though the release of toxins that cause gastrointestinal issues and skin irritation (State of the Lake 2008). Phosphorus loading in Lake Champlain thus threatens human health, aquatic biodiversity, and tourism revenue (Bloom 2010, Holmes et al. 1999). Just three percent of phosphorus pollution to Lake Champlain comes from point sources, a term which refers to large, easily identifiable sources of pollution like sewage treatment plants or major drainage pipes. The rest comes from diffuse, hard-to-pinpoint sources—lawns, agricultural fields, construction sites, eroding streambeds, roadside ditches, and parking lots—with agricultural and developed sources each accounting for about half of the total. Together, these are known as “non-point” sources.

Those who have followed Vermont’s decade-long struggle to clean up the lake can be forgiven for feeling dispirited. Since 2002, over $100 million in combined state and federal money has been spent, with negligible improvements in water quality (Page 2011). Of the thirteen sections of the lake, not one exhibits decreasing levels of phosphorous. In fact, four sections show increasing phosphorus levels (State of the Lake 2008). The January 2011 decision by the Environmental Protection Agency to challenge Vermont’s Total Maximum Daily Load (TMDL) for phosphorus and its “Clean and Clear” cleanup plan, further indicates the need for better controls and more effective actions.

In a warming world phosphorus loads are likely to increase, rather than decrease. With climate change, Vermont is likely experience more frequent heavy storm events, with runoff and floods which can account for up to 95% of phosphorus loading (Stager and Thill 2010). Climate change will likely increase precipitation across the board; Vermonters will see more winter rains rather than snow. Taken as a whole, the myriad effects of climate change will add to the stress on ecosystems like Lake Champlain. A 2009 Danish study found that climate change can be expected to increase phosphorus runoff and eutrophication in temperate lakes, a finding which may be reasonably applied to Lake Champlain (Jeppesen et al.). Even if Vermonters succeed in meeting current standards for phosphorus loading—an achievement we have been unable to accomplish in the past decade—science tells us that phosphorus loading will continue to worsen.

Why Vermonters and Visitors Should Care

The health of Lake Champlain is important to a wide range of Vermonters and others for a number of reasons. In Vermont, fishing and hunting guides, as well as owners of lakeside marinas, resorts, restaurants, motels, gas stations, general stores, and bed and breakfasts depend on lake-based tourism for their income. Thousands of residents and tourists enjoy the lake, fishing, hunting, swimming, boating, biking, and renting lakeside homes. Lake users care about phosphorus pollution because it diminishes the aesthetic and recreational value of the lake. They want to be able to enjoy the lake, and they want their children to be able to do so in the future. Furthermore, hundreds of homeowners invest in lakeside properties and pay property taxes in Vermont communities. Some of those lakeside communities draw drinking water directly from the lake. Blooms of blue-green algae can pose a health risk to those residents, as well as to swimmers and boaters; the bacteria in algae blooms have killed dogs in the past.

Other concerned citizens may have no direct economic interest in the lake or lakeside property, but care deeply about the ecological integrity and aesthetic beauty of the lake. In addition, the State of Vermont has a legal obligation—under the Clean Water Act and other environmental laws—to regulate phosphorus loading in Lake Champlain. Given the EPA's recent announcement that Vermont's TDML for phosphorus does not adequately control pollution, Vermont state agencies face increased pressure to bring the lake in compliance with federal standards.

In the face of daunting environmental problems, including global climate change, Lake Champlain presents a challenge that can be met. While concerted action will never restore the lake to a pre-1900 or pre-1850 levels of phosphorus, Vermonters can make a difference. With further research and monitoring, and informed action on every level from the household and town to the state and federal government, Lake Champlain can be stabilized and remediated. It will take time, care, and patience.

The following chapters represent the work of four student teams in the Spring 2011 Environmental Studies Senior Seminar at Middlebury College. Our hope is that the information and analyses presented herein will benefit watershed managers and town planners in their efforts to address phosphorus loading on a local, regional, and statewide level.

River Watch Data Analysis

Community Partner: Kristen Underwood, Consultant, and Addison County River Watch Collaborative

Chapter 1 of this report focuses on our efforts to analyze phosphorus loads in the watersheds of Addison County. We studied five watersheds, with rivers draining either into Otter Creek or directly into the Lake: Little Otter Creek, Lewis Creek, Middlebury River, New Haven River, and Lemon Fair River. The primary goal of this group was to provide watershed managers with an analysis of instream nutrient criteria, in particular phosphorus concentrations, determined by ecotype zones. Each stream type has different capacities for handling phosphorus based on the physical characteristics of the stream and its plants, insects, and fish. Criteria to protect natural conditions were differentiated by stream ecotype: small high-gradient (SHG), medium high-gradient (MHG), and warm water medium-gradient (WWMG). Prior to our work, no map existed depicting the stream ecotypes and coinciding nutrient criteria levels. Along with mapping the stream ecotypes for the Little Otter Creek watershed, we compiled existing monitoring data from an eight year period to assess which watersheds are contributing most heavily to phosphorus loading in Lake Champlain. Finally, we sought to compare instream phosphorus levels to loading targets for Lake Champlain. We hope the presentation and organization of such data proves meaningful for future analysis and action.

Roadside Ditches

Community Partner: Kristen Underwood, Consultant, and Addison County River Watch Collaborative

Chapter 2 is about the role roadside ditches play in contributing to the phosphorus levels in Lake Champlain. Roadside ditches are an extension of local stream networks. Therefore, phosphorus that enters roadside ditches in Vermont eventually flows into Lake Champlain. Phosphorus can enter roadside ditches through agricultural and urban runoff, as well as through sediment from road bank erosion. Well-maintained roadside ditches can minimize the effects of phosphorus from runoff or erosion, while poorly maintained roadside ditches can exacerbate the phosphorus issue.

This group analyzed ditches in the Little Otter Creek watershed. It created a methodology that used several factors to determine if a ditch was well or poorly maintained. By using this methodology on a manageable study area, the group was able to create a way to analyze roadside ditches that can be applied to watersheds across the state of Vermont.

Analyzing and Documenting Floodplain Development in the Addison County Region

Community Partner: Addison County Regional Planning Commission

Chapter 3 tells the story of floodplain development in the Addison Region. By intensifying erosion and runoff, land conversion and the construction of impervious surfaces along waterways are a significant source of phosphorus and threaten the water quality of the lake (Clean and Clear 2010). Development in zones at risk for flooding is also problematic because it unduly places people and property in danger. We produced updated town maps that show development within flooding zones, conducted a preliminary economic analysis of the assets at risk to floods, and collected stories from witnesses of floods in the Addison Region. An online interactive map synthesizes this information and makes it available to the public. By making the connection between phosphorus runoff and human risk, we hope to provide a compelling tool for policymakers to advocate—and legislate—against further floodplain development. Zoning that discourages development in floodplain zones reduces phosphorus runoff and also helps to prevent future flooding disasters (Clean and Clear 2010).

Improving Water Quality Language in Town Plans

Community Partner: Addison County Regional Planning Commission

Chapter 4 represents the work of our town planning group. In Vermont, each town is required to draft legally binding documents which set forth a collective vision for its future. Towns have significant but often overlooked power to shape zoning and development, which gives them a number of powerful tools for tackling phosphorus loading. Currently, the degree to which town planning language addresses phosphorus loading varies widely from town to town. Practically speaking, this means that there is significant room for improvement. Most town plans undergo review and revision every five years, which presents town boards with regular opportunities to enact more lake-friendly policy. Here in Middlebury, the Addison County Regional Planning Commission has spearheaded efforts to help towns adopt specific language to help prevent phosphorus runoff.

We worked in conjunction with the ACRPC to create a comprehensive review of the water quality-related policy language in the town plans of the twenty-one towns of Addison County. The document is meant to be a resource for town planners. It contains an analysis of each town's plan along with recommendations and a section containing 'model' town plan language with regards to water quality. Given that these town plans are legal documents, the group's focus has been on replacing weak language, identifying omissions, and making specific recommendations about existing water quality legislation, programs, and initiatives.

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Chapter 1. River Watch Data Analysis

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Introduction

The overall purpose of our project was to better understand phosphorus in Addison County's watersheds through the provided baseline data and monitoring reports. More specifically, we analyzed which watersheds are contributing the most phosphorus to Lake Champlain and how each stream meets the nutrient criteria levels for both acceptable stream integrity and for allowable loading into the lake, taking into consideration the structure and qualities of the stream. Our objectives were split into three segments: to map the ecotypes of each watershed to determine specific nutrient criteria needs of each segment of the streams; to analyze available monitoring data to draw meaningful conclusions about the current status of Addison County watersheds; and to propose future management recommendations. Our report will provide a preliminary methodology for identifying stream ecotypes and interpreting sampling results in the context of these stream ecotypes.

Phosphorus concentrations in Lake Champlain exceed allowable levels as determined by Vermont's Water Quality Standards. Monitoring efforts of the regional condition of Lake Champlain's water quality are led primarily by the Vermont Agency of Natural Resources, a state agency which houses the Department of Conservation, and by the Addison County River Watch Collaborative (ACRWC).

The ACRWC monitors the water quality of the six watersheds in Addison County. A network of volunteers conducts the sampling efforts, with logistic and technical assistance from Ethan Swift of the VTDEC Monitoring, Assessment and Planning Program and from Kevin Behm of the Addison County Regional Planning Commission. With the earliest monitoring efforts beginning in 1992 in the Otter Creek and the Lewis Creek watersheds, the ACRWC has collected a baseline of samples on water quality standards including phosphorus, nitrogen, turbidity, nitrates, sediment, and E. coli. Kristen Underwood of South Mountain Research & Consulting has worked closely with the ACRWC and provided us with the database of sampling results and a report on sampling results published in 2010.

In August 2009, the Vermont Department of Conservation's Water Quality Division released a document entitled, "Proposed Nutrient Criteria for Vermont's Lakes and Wadeable Streams" which proposes the integration of updated and specified nutrient criteria into the Vermont Water Quality Standards. The proposed nutrient criteria include standards for phosphorus, nitrogen and turbidity (the measure of suspended solids). Various criteria standards are presented, considering diverse needs including the biological integrity and aesthetic value of the streams. More importantly, the proposed values for total phosphorus are specifically defined according to stream structure as delineated by three stream ecotypes—small high-gradient, medium high-gradient, and warm water medium-gradient streams. Because phosphorus levels differ naturally in different types of streams, a finer-grained analysis of ecotypes will allow watershed managers to better match their expectations of how much phosphorus should be in the streams to the actual characteristics of the stream.

These ecotypes fundamentally determine phosphorus criteria for each watershed segment, but watershed managers face the challenge of not knowing how to apply the criteria due to the absence of an overarching map or list of stream assessment ecotypes. Some work has been done by the state to develop a probability value or parameters that determine each ecotype, but more research and analysis needs to be done to determine a method for designating ecotypes and thus nutrient criteria to management areas.

The Middlebury College ES401 River Watch group has assisted in the data assessment efforts that these watershed groups have begun. A large amount of monitoring data already exists thanks to the efforts of groups such as ACRWC, but management of this data is an ongoing task. Through an informed process with the guidance of watershed groups, we have organized existing data and presented it in a meaningful way to assist watershed groups in their analysis and in directing any future action.

Objective #1: Mapping

Creating an Ecotype Map of Lake Champlain's Watersheds: GIS Workflow and Data Sources

The original delineation of ecotypes was determined primarily by aquatic biologists at the Department of Environmental Conservation (VTDEC) based on biological indexes such as the presence of plant and animal aquatic species. Within the scope of our project, however, we created a methodology for determining ecotypes based on physical rather than biological attributes. The VTDEC has a set of defined parameters for doing so, based on a survey of one hundred streams across the state of Vermont. We used the parameters of four physical variables—elevation, stream order, gradient, and upstream drainage area—to assign ecotypes to the reaches of Little Otter Creek. Upon consultation with aquatic biologists at the Water Quality Division, we determined that this consideration of physical properties of streams served as a good first-cut delineation of ecotypes.

We first attempted to distinguish ecotypes for the Little Otter Creek watershed based on stream reaches as previously defined by the Vermont Center for Geographic Information (VCGI). VCGI makes available a Vermont Hydrology (Water_VHDCARTO_line) shapefile that contains stream order for each stream reach. We then downloaded geomorphic reach (s05swfinaldslv) and geomorphic reach breaks (s06rpts) shapefiles from the Stream Geomorphic Assessment Data Management System website (SGA-DMS). Reach breaks are point features on stream reaches that contain data specific to that reach, such as channel length. The attributes of these geomorphic reach breaks therefore provided us with information for each stream reach, including drainage area and gradient. Unfortunately, the stream reach datafiles from the SGA-DMS site did not include stream order. Therefore, to allocate each stream reach a stream order, we then spatially joined stream order from the VCGI data layer to the geomorphic reaches for Little Otter Creek watershed. As for elevation, the SGA-DMS datafiles contained upstream and downstream elevation for each stream reach. We tabulated an average and determined this to be representative of the average elevation of the stream reach.

Table 1.1 shows the parameters of the four physical variables for each ecotype which were used in determining ecotypes. The wide range of values reflects the fact that many of these ecotype characteristics overlap. It is the combination of these physical variables that speaks to the specificity of ecotype, though the wide ranges of these physical parameters means that stream reaches have the potential to fall under multiple ecotypes. In the case of the Little Otter Creek watershed, we found that out of the twenty-three stream reaches we evaluated, eighteen were clearly of one ecotype, while the other five fell into two ecotype categories. Appendix 1.1 displays the delineation of these stream reaches.

Table 1.1. Parameters of physical variables per ecotype.

	Small High-Gradient (SHG)	Medium High-Gradient (MHG	Warm Water Medium Gradient (WWMG)	Slow Winder (SW)
Elevation (ft)	840-2500	290-1624	140-900	100-1339
Stream Order	1-3	1-4	1-5	1-3
Gradient	>1%	>1%	<1%	<1%
Drainage Area (km^2)	0.6-95	1-513	10-1781	4-60

Source: *Biocriteria for Fish and Macroinvertebrate Assemblages in Vermont Wadeable Streams and Rivers.* VTDEC, 2004

Figure 1.1 potrays the ecotype map of Little Otter Creek and shows that the majority of Little Otter Creek is of the warm-water medium gradient (WWMG) ecotype. Ecotypes of certain reaches were harder to determine because their characteristics fell between more than one ecotype.

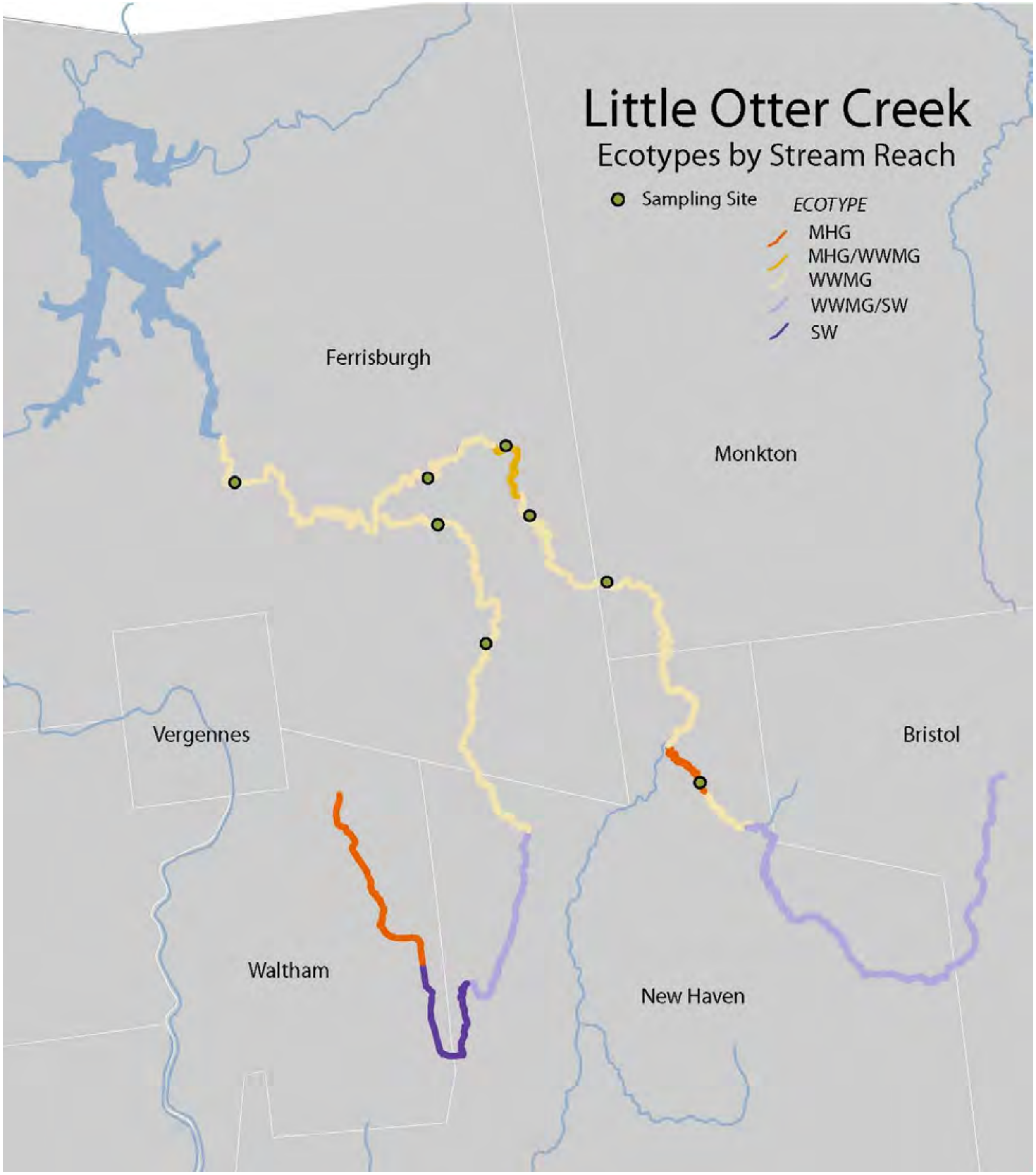

Figure 1.1. Little Otter Creek ecotypes by stream reach.

Conclusion

Our attempt at determining ecotypes in the Little Otter Creek will allow us to evaluate the performance of the streams in this sub-watershed, since the nutrient criteria can now be paired with an ecotype for each stream reach and can be compared to actual phosphorus concentration levels. The overlapping of ecotypes in certain stream reaches was expected and not entirely problematic because the characteristics of streams as occuring in nature would not change abruptly according to boundaries that are pre-determined by humans. As such, while this method can be replicated for other watersheds with the data that are available from the sources mentioned above, it is important to recognize that it contains limitations that affect the accuracy of ecotype delineation. Since multiple other physical, biological and physio-chemical factors influence ecotype, they must be considered for a more complete and precise evaluation. Critical to an integral determination of ecotype is also the process of ground verification, since natural conditions change and existing data sources may not accurately reflect ground conditions. Finally, while ecotype and its determinant variables are currently the primary indicator of nutrient criteria, it is important to consider other conditions on the ground, such as land use in the surrounding area, that are not captured in these categories but that may also affect the capacity of a stream to handle its phosphorus load.

Objective #2: Phosphorus Data

Methods

Overview

Five of the six watersheds (Little Otter Creek, Lewis Creek, Middlebury River, New Haven River, and Lemon Fair River) in Addison County were analyzed for phosphorus pollution from 2003 to 2010 (Figure 1.2). Otter Creek was not analyzed for phosphorus pollution as per the suggestion of community partner, Kristen Underwood. Sampling between 1992 and 2002 was not included due to a desire for more recent data analysis. Vermont instream nutrient criteria (*Proposed Nutrient Criteria for Vermont's Lakes and Wadeable Streams*, 27-28) were used to determine the degree of phosphorus pollution in Little Otter Creek.

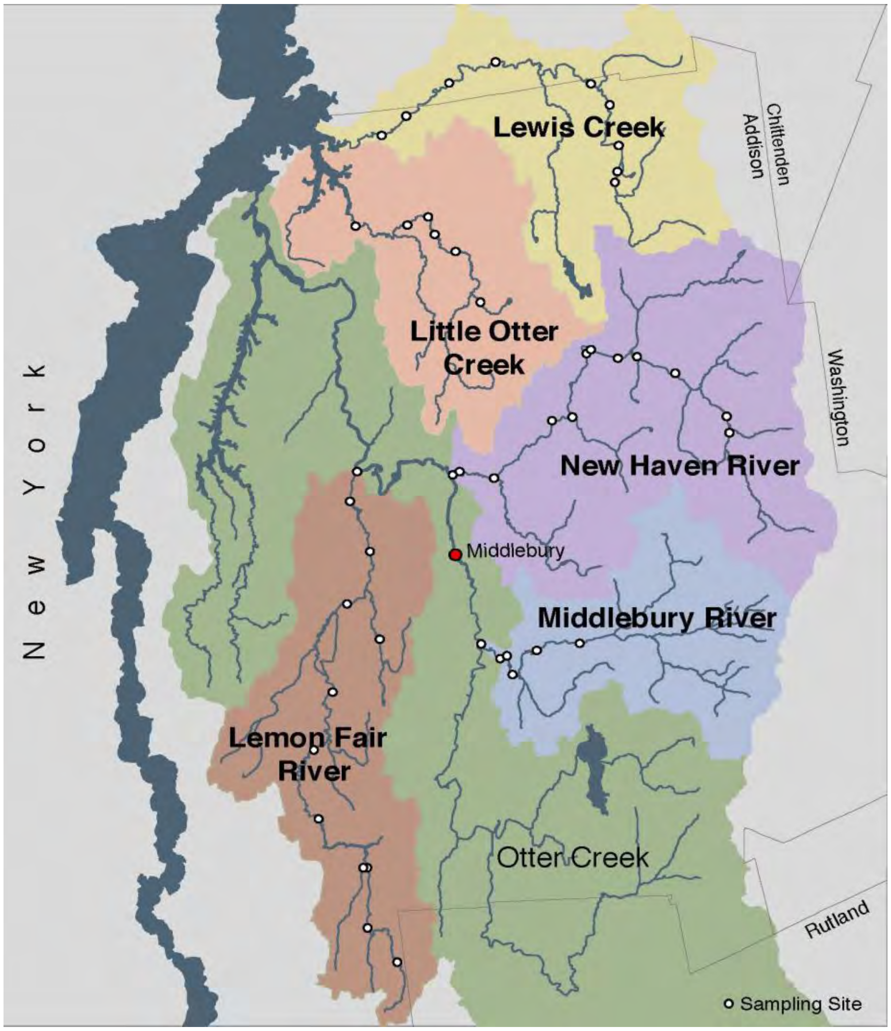

Figure 1.2. Five Watersheds (Lewis Creek, Little Otter Creek, New Haven River, Middlebury River, and Lemon Fair River) and the sampling stations within each that were analyzed for phosphorus pollution between 2003 and 2010.

Phosphorus Concentration Data

Water samples were collected at each sampling station by the ACRWC (Table 1.2). Total phosphorus (TP) concentrations for specific sampling stations within each watershed during the summer months (June-September) from 2003 to 2010 were obtained from the Addison County River Watch Collaborative (ACRWC) database. Other months of the year (March, April, and October) were excluded because Vermont total phosphorus criteria for wadeable streams are applicable for the months of May through September (Hoadley, 22). The month of May was additionally excluded as per the suggestion of Community Partner Kristen Underwood because of continuous spring runoff and flooding from precipitation.

Table 1.2. Sampling stations within each watershed where water samples were collected.

Watershed	Sampling Stations										
Little Otter Creek	LOC 10	LOC 11	LOC 14.4	LOC 4.3	LOC 7.8	LOC 8	LOC NEW				
Lewis Creek	LCR 14	LCR 15.6	LCR 17.2	LCR 18.6	LCR 19.5	LCR 3.7	LCR 5.2	LCR 7.25	LCR 9.9		
Middlebury River	MIR 0	MIR 1	MIR 1.5	MIR 2	MIR 3	MIR 5.7					
New Haven River	NHR .5	NHR 0	NHR 10.5	NHR 11.5	NHR 13	NHR 15	NHR 15.5	NH R2	NH R5	NH R6	NHR 8	NHR 9
Lemon Fair River	LFB 2.5	LFR 0	LFR 1.2	LFR 12	LFR 15.8	LFR 20.2	LFR 23.9	LFR 26.6	LFR 29.3	LFR 3.7	LFR 6.7	LFT 0.1

Annual averages and standard deviations of the TP concentrations at each sampling station were calculated. All averages and standard deviations were calculated with at least three samples collected on non-consecutive days. All annual averages and standard deviations for each sampling site in a specific watershed are in Appendices 1.2-1.6.

Instream Nutrient Criteria for TP

Proposed instream nutrient criteria for TP concentrations in wadeable streams in Vermont are based on the ecotype zones of sampling stations within a watershed (Table 1.3). To determine the ecotype zones, a variety of factors (gradient, drainage area, stream order, and elevation) of the surrounding ecosystem were extracted from ArcGIS in Task #1 of this study. The determined nutrient criteria were then compared to the annual average TP concentrations.

Table 1.3. Instream nutrient criteria for TP proposed by the State of Vermont for specific ecotype zones.

Stream Ecotype	TP Nutrient Criteria (mg/L)
Small, high-gradient (SHG)	0.022
Medium, high-gradient (MHG)	0.013
Warm-water, medium gradient (WWMG)	0.011

Source: Proposed Nutrient Criteria for Vermont's Lakes and Wadeable Streams, 27-28

Results

For each watershed, a map is provided to show the location of each sampling station within the watershed along with charts showing the pattern of annual average phosphorus pollution at each sampling site. Annual average TP concentrations per year at each sampling station are displayed in two charts for each watershed to show the pattern of phosphorus pollution upstream to downstream: one from 2003-2006 and one from 2007-2010. The data were displayed over two charts as opposed to one chart because interpretation and readability were easier. No samples were taken in 2009 and not all sampling stations were included between 2007 and 2010 because of budget cuts within the ACRWC. Nutrient criteria for the Little Otter Creek watershed were based on mapped ecotypes. Analyses for the other watersheds were based on the high level of the range of criteria over ecotype zones (0.011 to 0.022 mg/L). The red lines on all bar graphs (except for Little Otter Creek) indicate this nutrient criteria level of 0.022 mg/L.

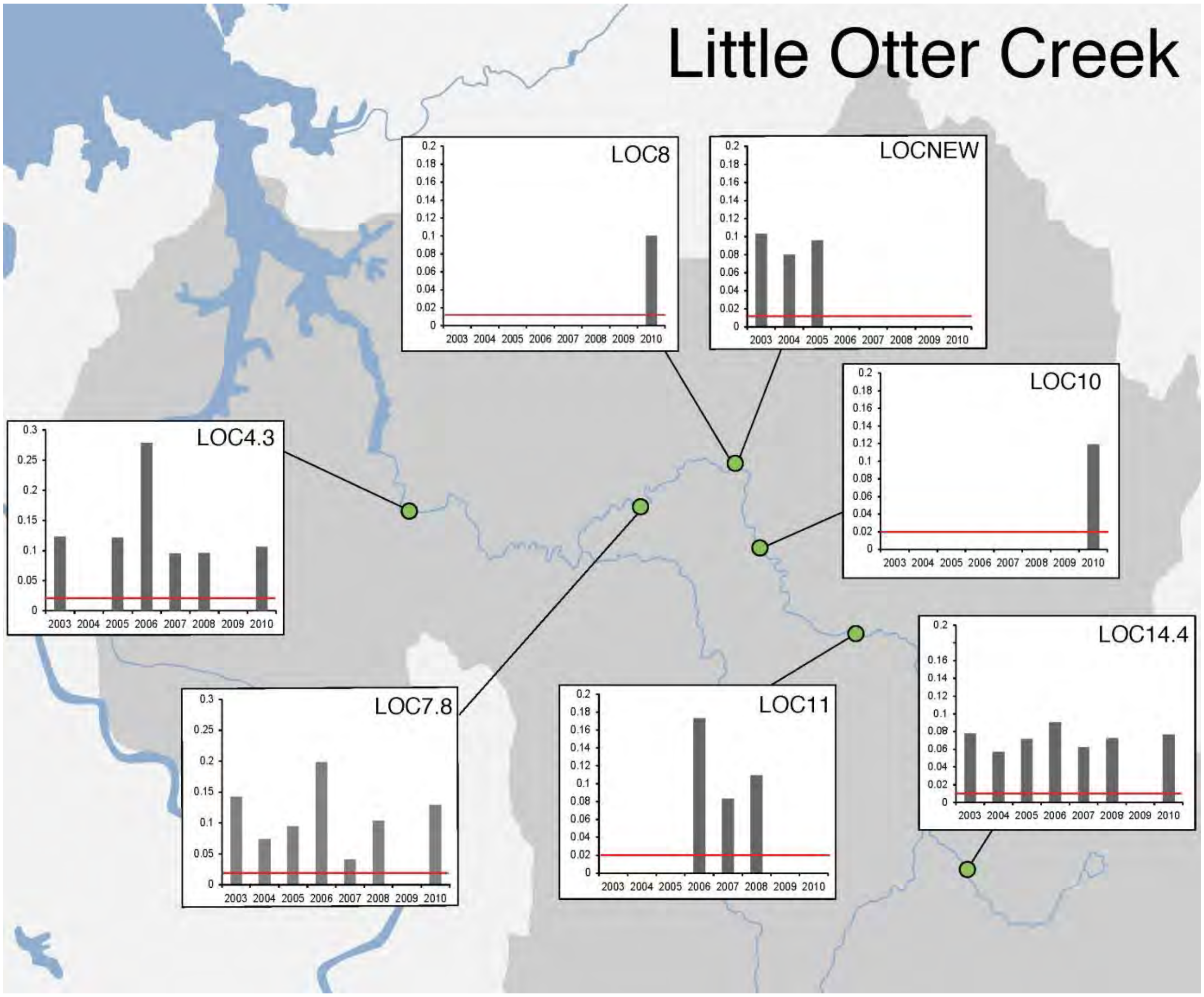

Figure 1.3. Average phosphorus concentrations in the Little Otter Creek watershed at each sampling station. The red line indicates the nutrient criteria based on ecotype and the gray bars represent the annual average phosphorus concentrations.

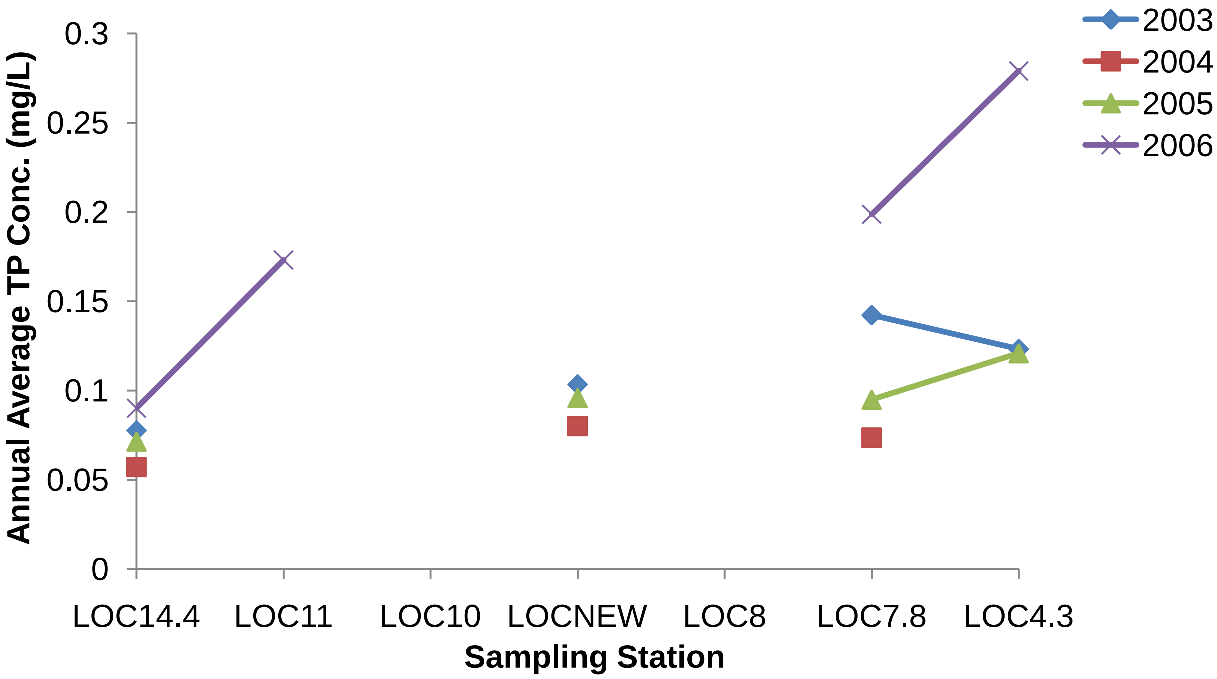

Figure 1.4. Average TP concentrations for each sampling station between 2003 and 2006 in Little Otter Creek. LOC14.4 is the most upstream sampling station while LOC4.3 is the most downstream sampling station.

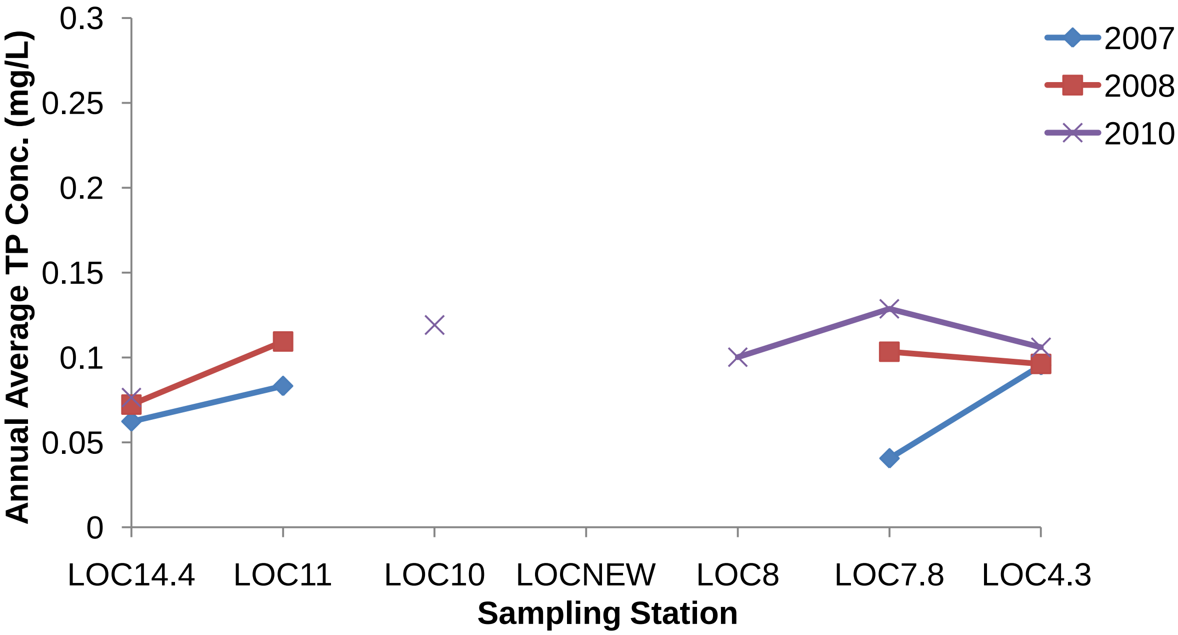

Figure 1.5. Average TP concentrations for each sampling station between 2007 and 2010 in Little Otter Creek. LOC14.4 is the most upstream sampling station while LOC4.3 is the most downstream sampling station.

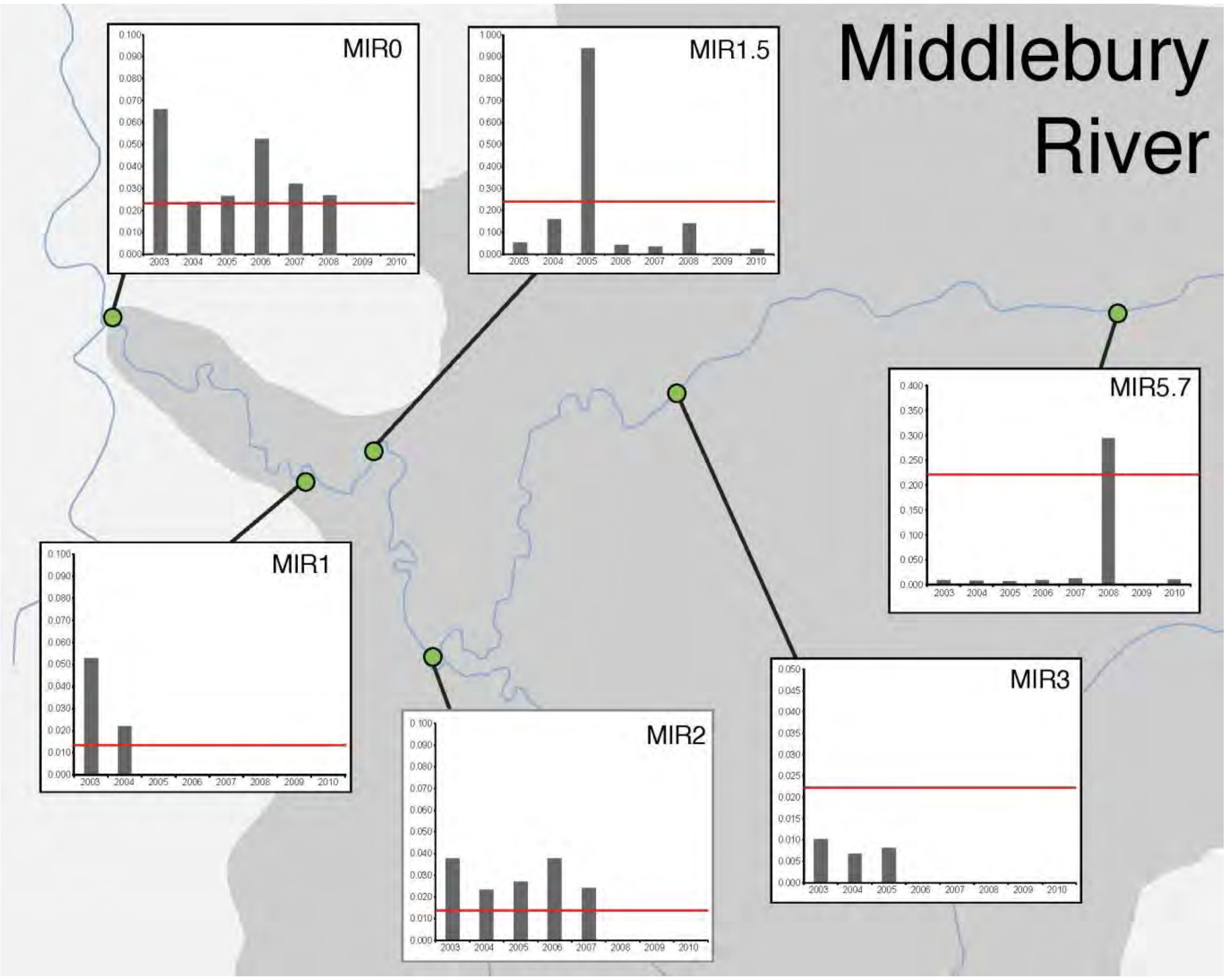

Figure 1.6. Average phosphorus concentrations in the Middlebury River watershed at each sampling station. The red line indicates the high-end nutrient criteria and the gray bars represent the annual average phosphorus concentrations.

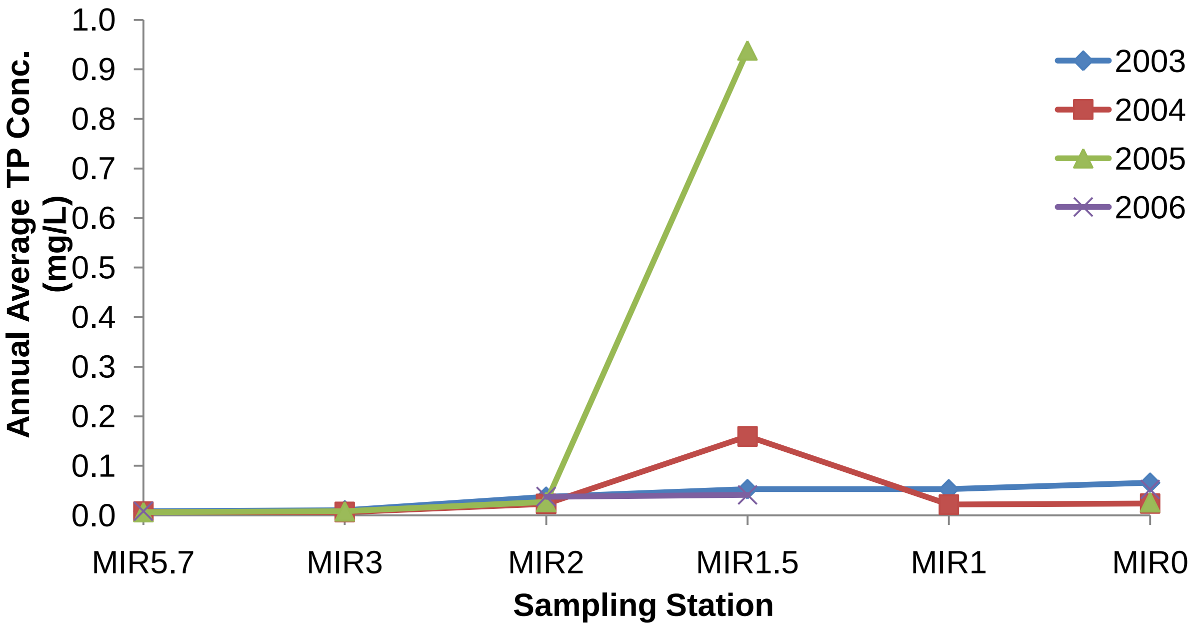

Figure 1.7. Average TP concentrations for each sampling station between 2003 and 2006 in the Middlebury River. MIR5.7 is the most upstream sampling station while MIR0 is located at the mouth of the river.

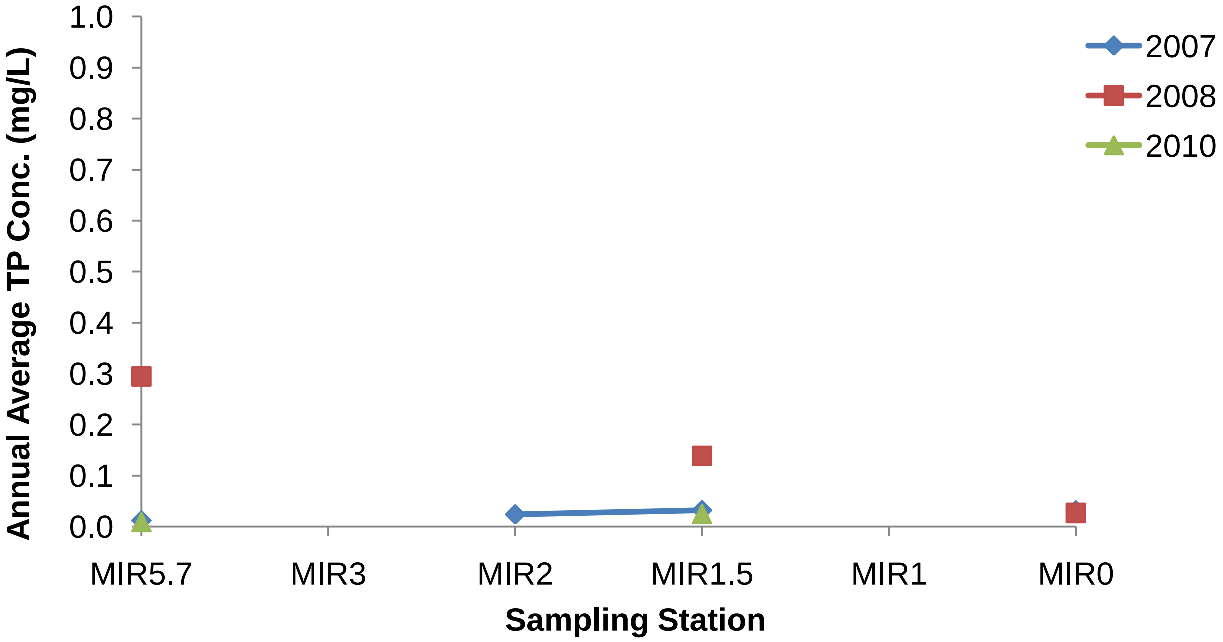

Figure 1.8. Average TP concentrations for each sampling station between 2007 and 2010 in the Middlebury River. No samples were taken in 2009. MIR5.7 is the most upstream sampling station while MIR0 is located at the mouth of the river.

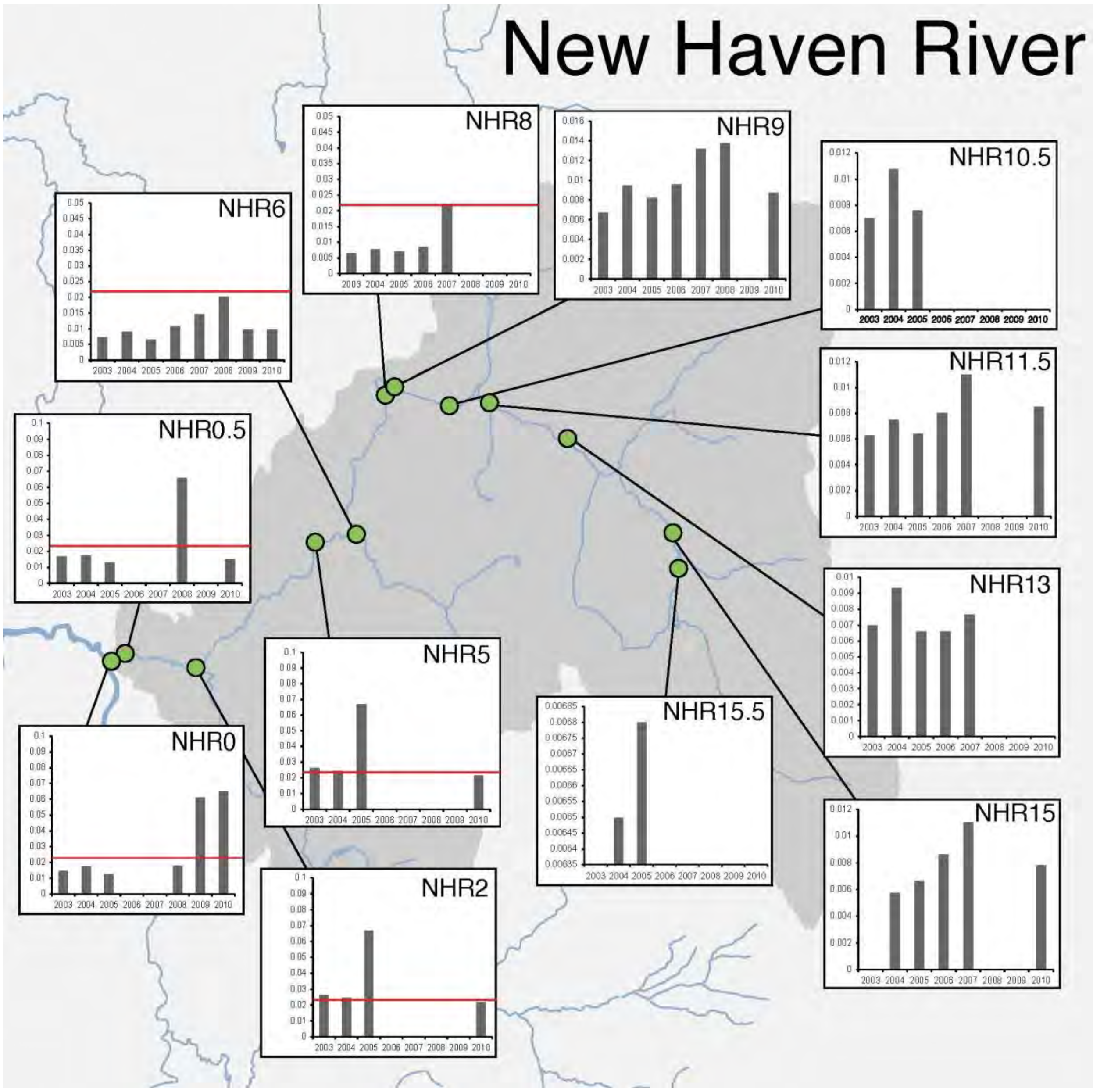

Figure 1.9. Average phosphorus concentrations in the New Haven River watershed at each sampling station. The red line indicates the high-end nutrient criteria and the gray bars represent the annual average phosphorus concentrations. Nutrient criteria lines are omitted from some of the plots due to the scale of the sampling results.

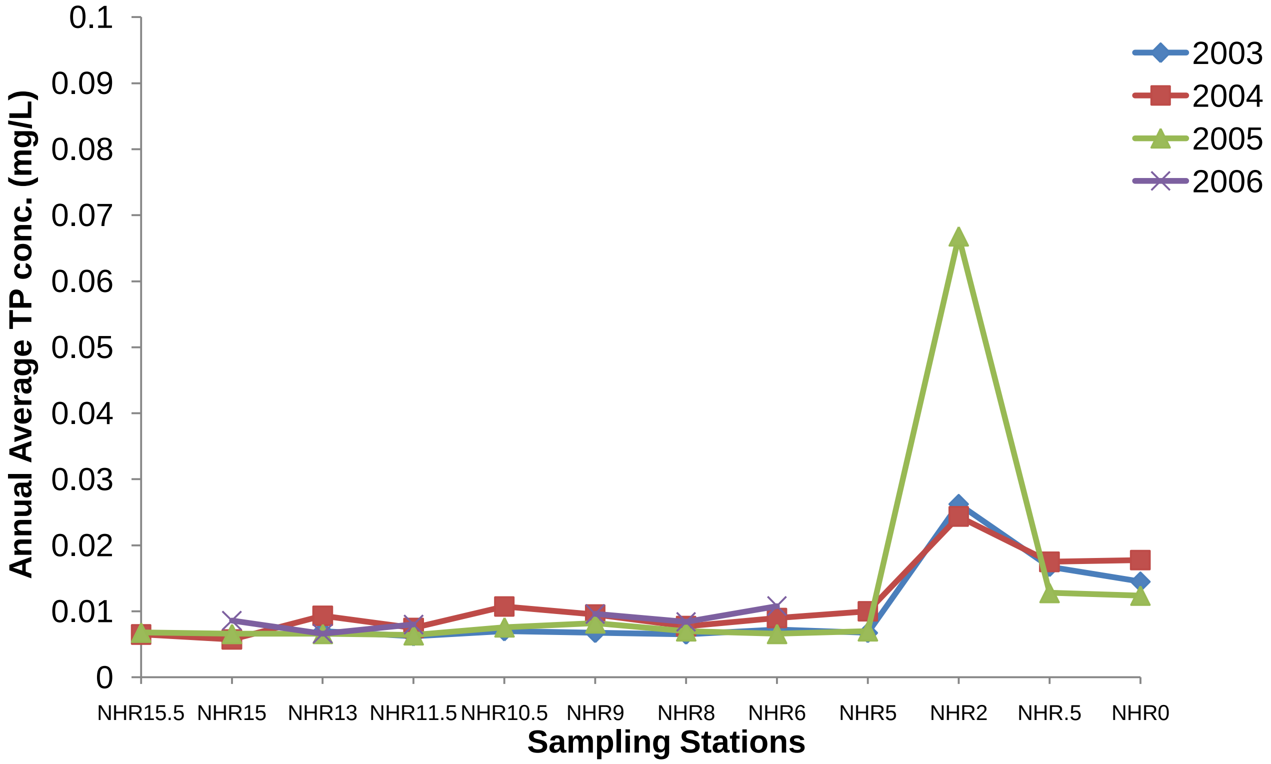

Figure 1.10. Average TP concentrations for each sampling station between 2003 and 2006 in the New Haven River. NHR15.5 is the most upstream sampling station while NHR0 is located at the mouth of the river.

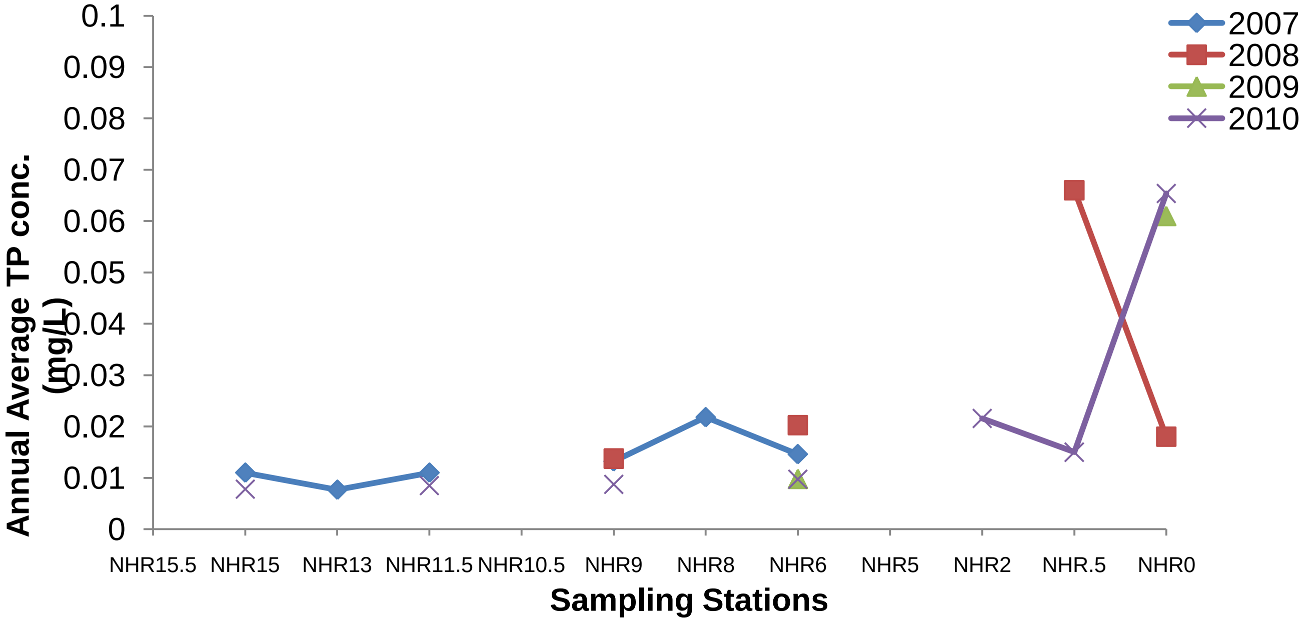

Figure 1.11. Average TP concentrations for each sampling station between 2007 and 2010 in the New Haven River. NHR15.5 is the most upstream sampling station while NHR0 is the most downstream sampling station.

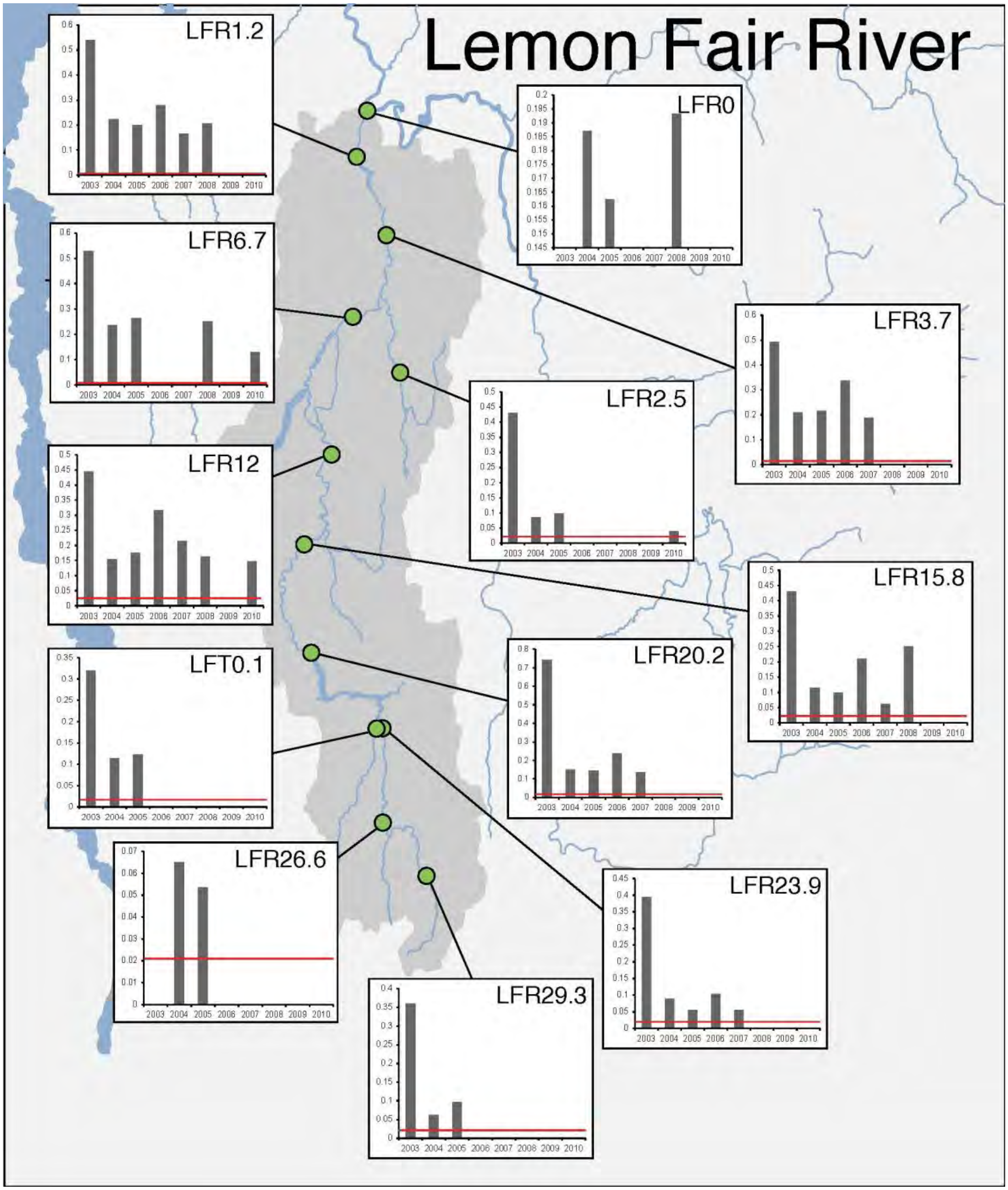

Figure 1.12. Average phosphorus concentrations in the Lemon Fair River watershed at each sampling station. The red line indicates the high-end nutrient criteria and the gray bars represent the annual average phosphorus concentrations. Nutrient criteria lines are omitted from some of the plots due to the scale of the sampling results.

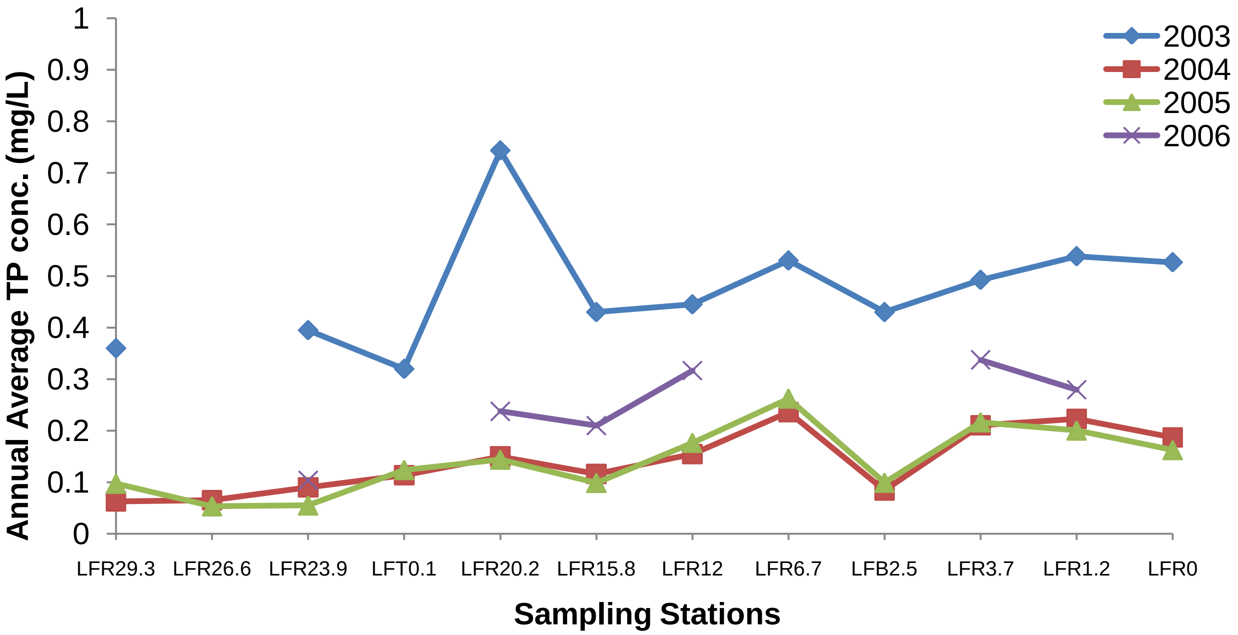

Figure 1.13. Average TP concentrations for each sampling station between 2003 and 2006 in the Lemon Fair River. LFR29.3 is the most upstream sampling station while LFR0 is the most downstream sampling station.

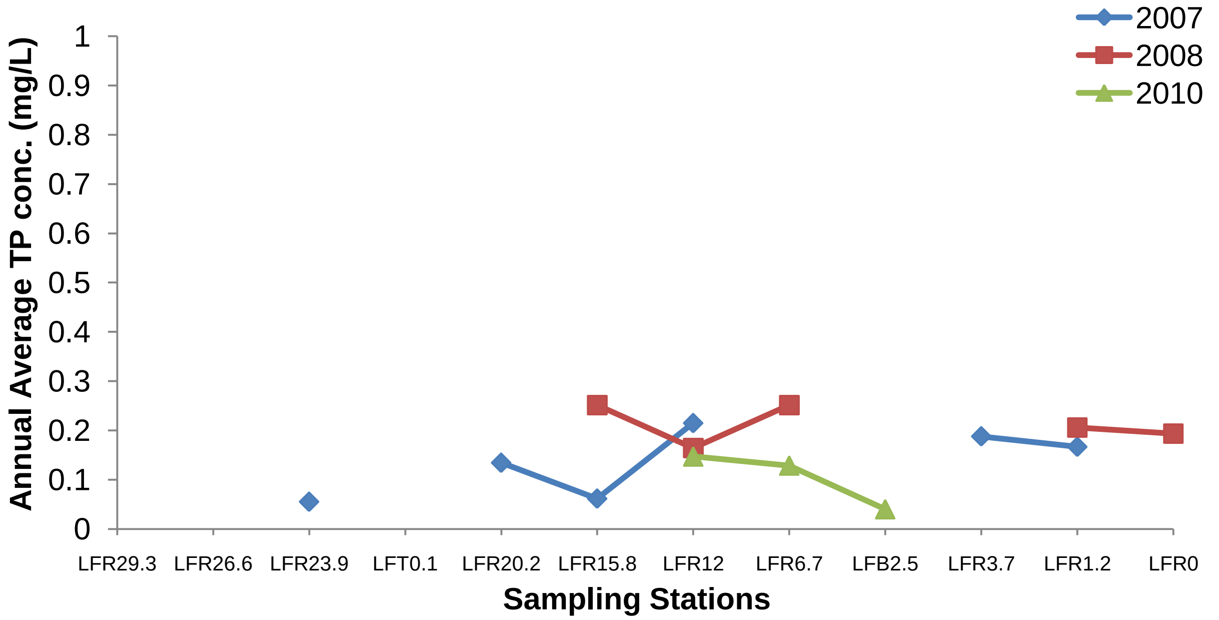

Figure 1.14. Average TP concentrations for each sampling station between 2007 and 2010 in the Lemon Fair River. No samples were taken in 2009. LFR29.3 is the most upstream sampling station while LFR0 is the most downstream sampling station.

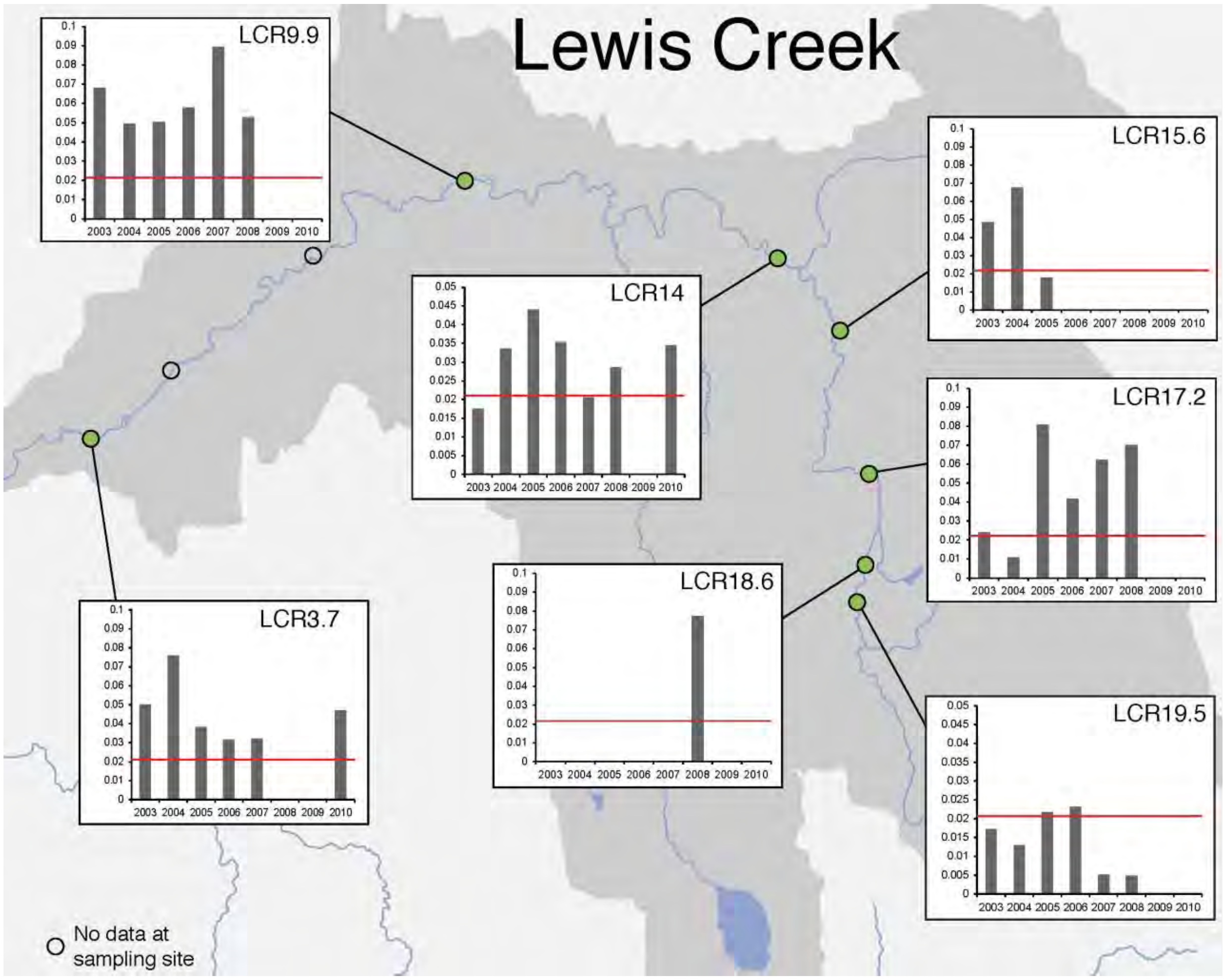

Figure 1.15. Average phosphorus concentrations in the Lewis Creek watershed at each sampling station. The red line indicates the high-end nutrient criteria and the gray bars represent the annual average phosphorus concentrations.

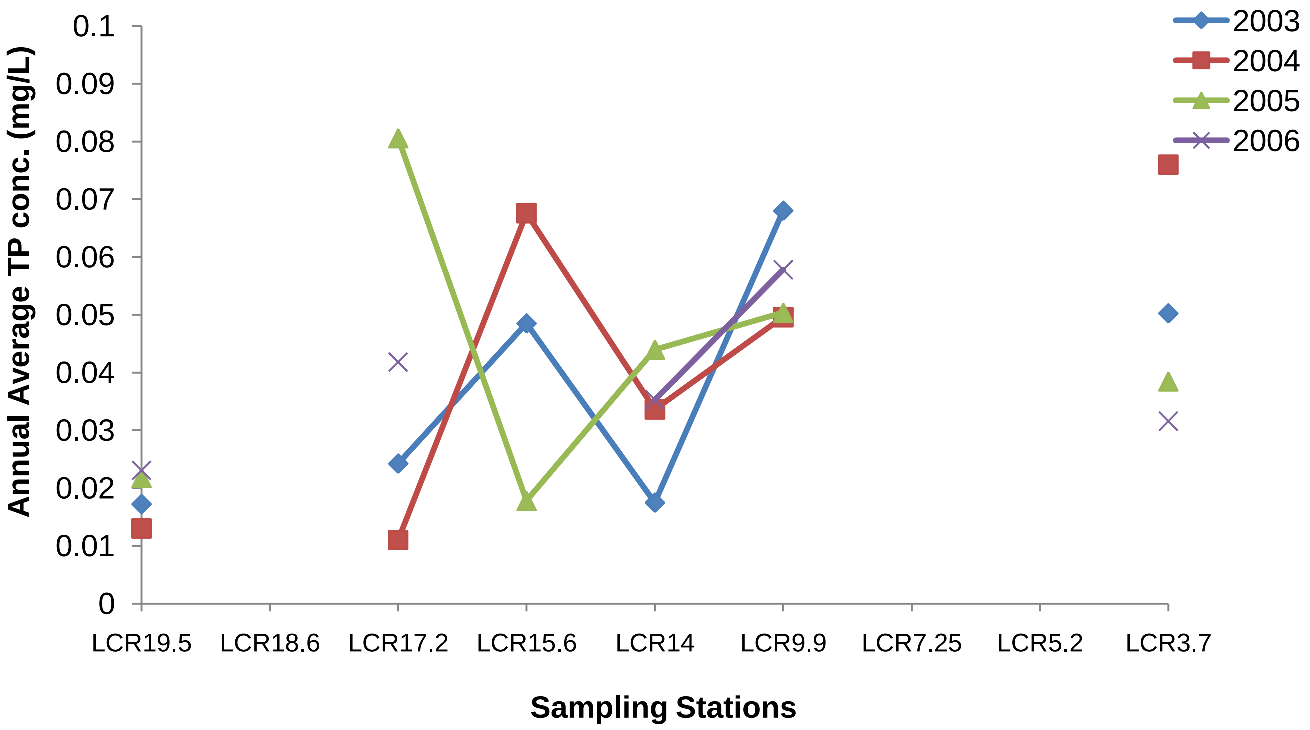

Figure 1.16. Average TP concentrations for each sampling station between 2003 and 2006 in Lewis Creek. LCR19.5 is the most upstream sampling station while LCR3.7 is the most downstream sampling station.

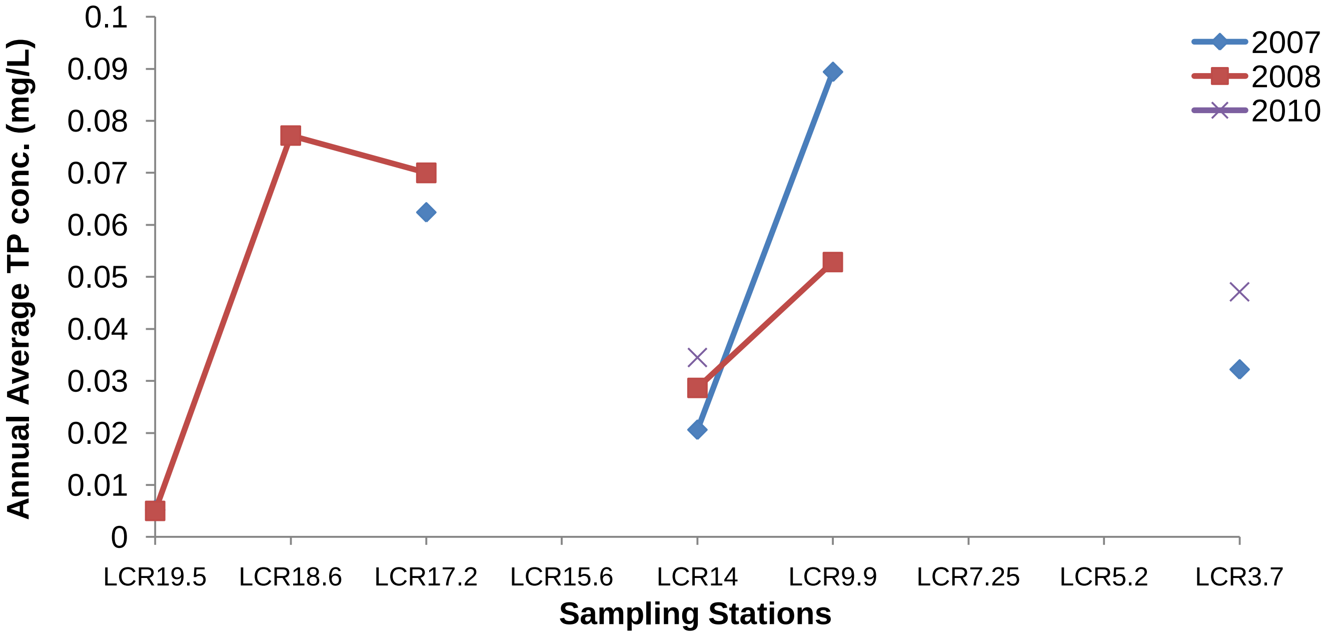

Figure 1.17. Average TP concentrations for each sampling station between 2007 and 2010 in Lewis Creek. LCR19.5 is the most upstream sampling station while LCR3.7 is the most downstream sampling station.

Discussion

Ecotype zones and therefore nutrient criteria were only determined for the Little Otter Creek watershed. The nutrient criteria ranged from 0.011 to 0.022 mg/L for all ecotype zones (Table 1.3). All other watersheds were analyzed based on this range of criteria, using 0.022 mg/L as the upper limit.

Little Otter Creek

Little Otter Creek phosphorus concentrations are exceeding nutrient criteria by a significant amount at all sampling stations (Figure 1.3). The sampling station that seems to most exceed the nutrient criteria is LOC4.3, located at the mouth of the river. This may be due to a build up of phosphorus pollution as the water flows from upstream to downstream which can be confirmed by Figures 1.4 and 1.5. Overall, 2006 seems to be a year of high phosphorus pollution which could be attributed to flood events or storm runoff.

Middlebury River

Phosphorus concentrations exceed the nutrient criteria at the mouth of the Middlebury River, but not as significantly as at the mouth of Little Otter Creek (Figure 1.6). Years to note are 2005 and 2008 at sampling stations MIR1.5 and MIR 5.7, respectively. Reasons for such high concentrations could be attributed to significant phosphorus polluters such as residential development or agricultural runoff. Figure 1.7 shows there is a slight increase of phosphorus concentration from upstream to downstream between 2003 and 2006. The opposite is true in 2008 (Figure 1.8) as phosphorus concentrations decrease from upstream to downstream.

New Haven River

Phosphorus concentrations are relatively low and do not exceed nutrient criteria at upstream sampling sites (Figure 1.9). However, downstream sampling stations show a pattern of higher phosphorus concentrations. Figures 1.10 and 1.11 show an increase in phosphorus concentrations upstream to downstream as well. NHR2 is significantly high between 2003 and 2006. Overall, the New Haven River is significantly less polluted than Little Otter Creek.

Lemon Fair River

Average annual phosphorus concentrations were exceeded at all sampling stations (Figure 1.12). The year 2003 had significantly higher concentrations at all sampling stations as evident from Figures

1.13 and 1.14. Phosphorus concentrations increased downstream to upstream between the years 2003 to 2006.

Lewis Creek

No sampling data were taken for sites LCR7.25 and LCR5.2 between the years of 2003 to 2010. Overall, phosphorus concentrations do not meet the nutrient criteria (Figure 1.15). The most downstream sampling site (LCR19.5) has the lowest phosphorus concentration. Average annual phosphorus concentrations for sampling sites other than LCR19.5 were variable between years and ranged from 0.01 to 0.09 mg/L (Figures 1.16 and 1.17).

Limitations and Challenges

Data are not available for every year and every sampling site. Thus, there are gaps within the analyzed data and graphs that made it difficult to assess trends over time. Community volunteers collect the samples using a set of protocols in order to ensure reliability. However, one must account for a certain amount of error in instrumentation and sampling. We accounted for this error by calculating the standard deviations of the phosphorus concentration averages (Appendices 1.2-1.6).

Conclusion

Most watersheds had an increase of total phosphorus concentrations from upstream to downstream; most upstream sampling stations had lower phosphorus concentrations than downstream sampling stations located at the mouth of the river. This trend could be attributed to accumulated phosphorus loading through the course of the river from nonpoint sources such as agricultural and residential runoff. Little Otter Creek had the highest relative phosphorus concentrations between 2003 and 2006. However, phosphorus concentrations exceeded nutrient criteria in all of the watersheds.

Objective #3: Lake Champlain Loading Targets

The above sections have reported on the instream levels of phosphorus and how they relate to the applicable nutrient criteria, determined by the ecotype of the stream section and the intended user group. However, the nutrient criteria discussed above relate only to the instream biological integrity and aesthetic value. The criteria to which the sampling data were compared above do not include any consideration of the phosphorus target loads for Lake Champlain. The watersheds in Addison County are part of the complex network of streams that drain into Lake Champlain and thus consideration of how instream nutrient levels meet loading targets and contribute to the lake Total Maximum Daily Load (TMDL) is another essential point of analysis. This section will report on phosphorus loading of two Addison County watersheds, Lewis Creek and Little Otter Creek, into Lake Champlain.[1]

Target loads for sub-basins of Lake Champlain calculated by the Vermont and New York Department of Environmental Conservation (1997) are frequently referenced as the target phosphorus loads for Lake Champlain. The Lake Champlain Basin Program uses these criteria in their "State of the Lake and Ecosystem Indicators Report" to evaluate the health of the lake. However, Medalie and Smeltzer (2004) identified the need for criteria for more specific than that at the sub-basin level. They derived, from the given VT and NY DEC targets and monitoring data, target loads for main tributaries in each sub-basin. In this 2004 report, they calculated annual phosphorus loads at the mouth of each tributary between 1991 and 2000 and compared the levels to the suggested target load. In 2009, the Lake Champlain Basin Program released a report estimating mean annual phosphorus load, on a two year basis to use a sufficient sample size, at the mouth of each tributary between the years of 1991 and 2008 using the FLUX program protocol of the US Army Corps of Engineers. Using the tributary target loads proposed by Medalie and Smeltzer and the estimated loads calculated by LCBP, we analyzed the state of Lewis Creek and Little Otter Creek (Figure 1.18).

Both Lewis Creek and Little Otter Creek have consistently exceeded proposed phosphorus loading targets across the studied years. The level to which each tributary exceeded the target load was substantial. In six and seven of the nine time periods, phosphorus loading levels from Lewis Creek and Little Otter Creek, respectively, more than doubled the target. Interestingly, the levels of phosphorus loading and the annual patterns in Lewis Creek did not match those of Little Otter Creek. Potential causes of these differences are natural variation, or different levels of water flow and precipitation.

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[1] Analysis was limited to these two watersheds based on available flow data from the only two USGS flow gages in Addison County.

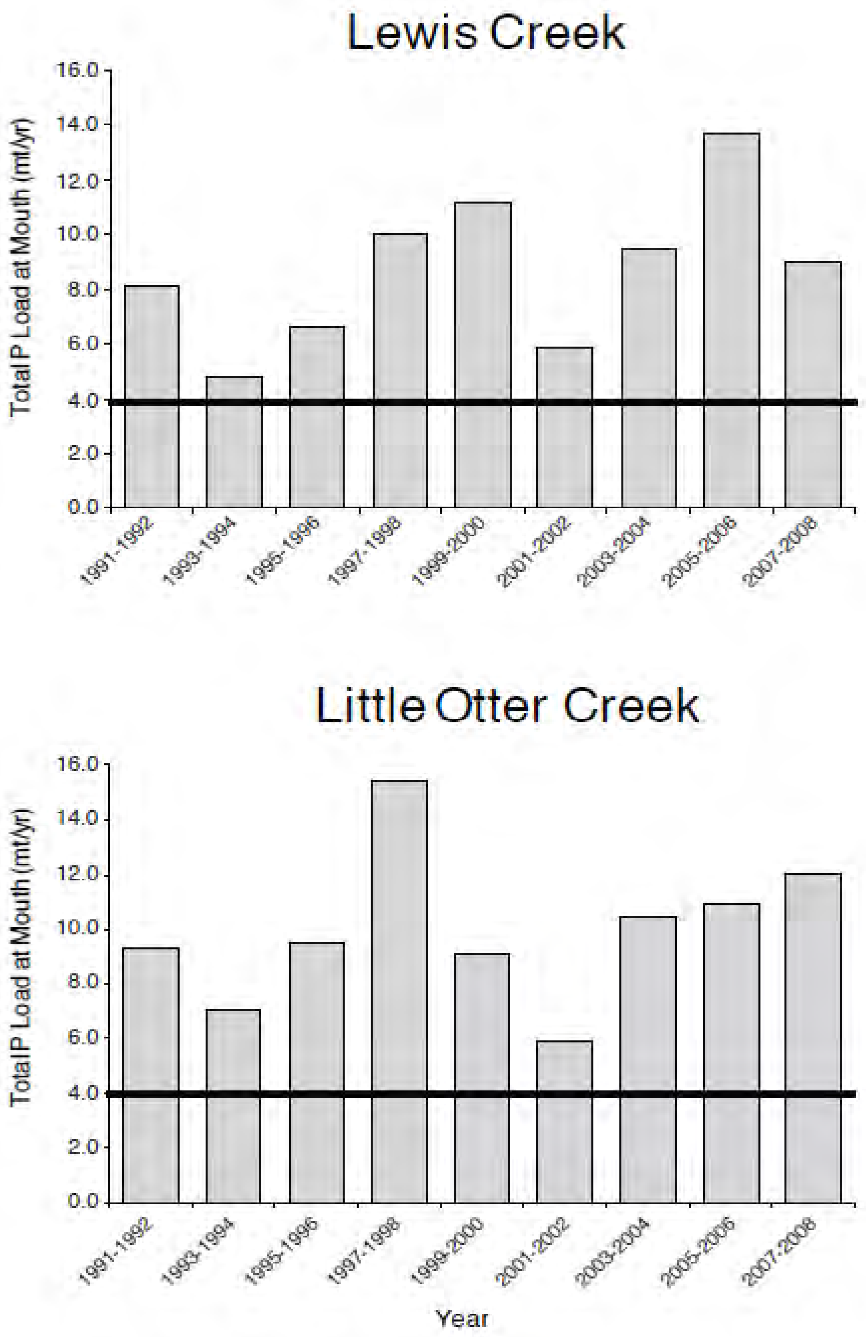

Figure 1.18. Annual phosphorus loading to Lake Champlain as compared to loading targets. The loading data were calculated in the "Lake Champlain Phosphorus Concentrations and Loading Rates, 1990-2008" report from the Lake Champlain Basin Program. The criteria line represents the proposed target load for each tributary: 3.9 mt/year for Lewis Creek and 4.0 mt/yr for Little Otter Creek, as estimated by Medalie and Smeltzer (2004).

To further understand the causes of these exceedances and differences between Lewis Creek and Little Otter Creek, we analyzed how the flow levels in each tributary relate to instantaneous phosphorus loads. We used the sampling events from the ACRWC, at sites LCR 3.7 and LOC 4.3, as sample points for our analysis. Flow rate data were obtained from the USGS National Water Information System. USGS gages are situated on each tributary very near to the ACRWC sample sites. Instantaneous phosphorus loading levels were calculated by multiplying phosphorus concentrations to flow rates (Appendix 1.7).[2] Phosphorus concentrations were obtained from the ACRWC sampling records. Because the time of sampling events from the ACRWC is unknown, we deemed an annual daily flow rate to be the best representation of flow rate at the unknown time of the sample. For the sake of comparison, only sampling events that occurred on the same day at both tributaries are including in this analysis. Results show a relationship between the flow rate and the instantaneous loads (Figure 1.19). However, it is unclear why at certain sampling events one tributary measures significantly higher levels of flow rate and phosphorus load. More research should be done to examine the differences between the two tributaries. Variables such as drainage area, precipitation rates, upstream land use, and stream integrity should be examined.

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[2] Methodology suggested by Kristen Underwood.

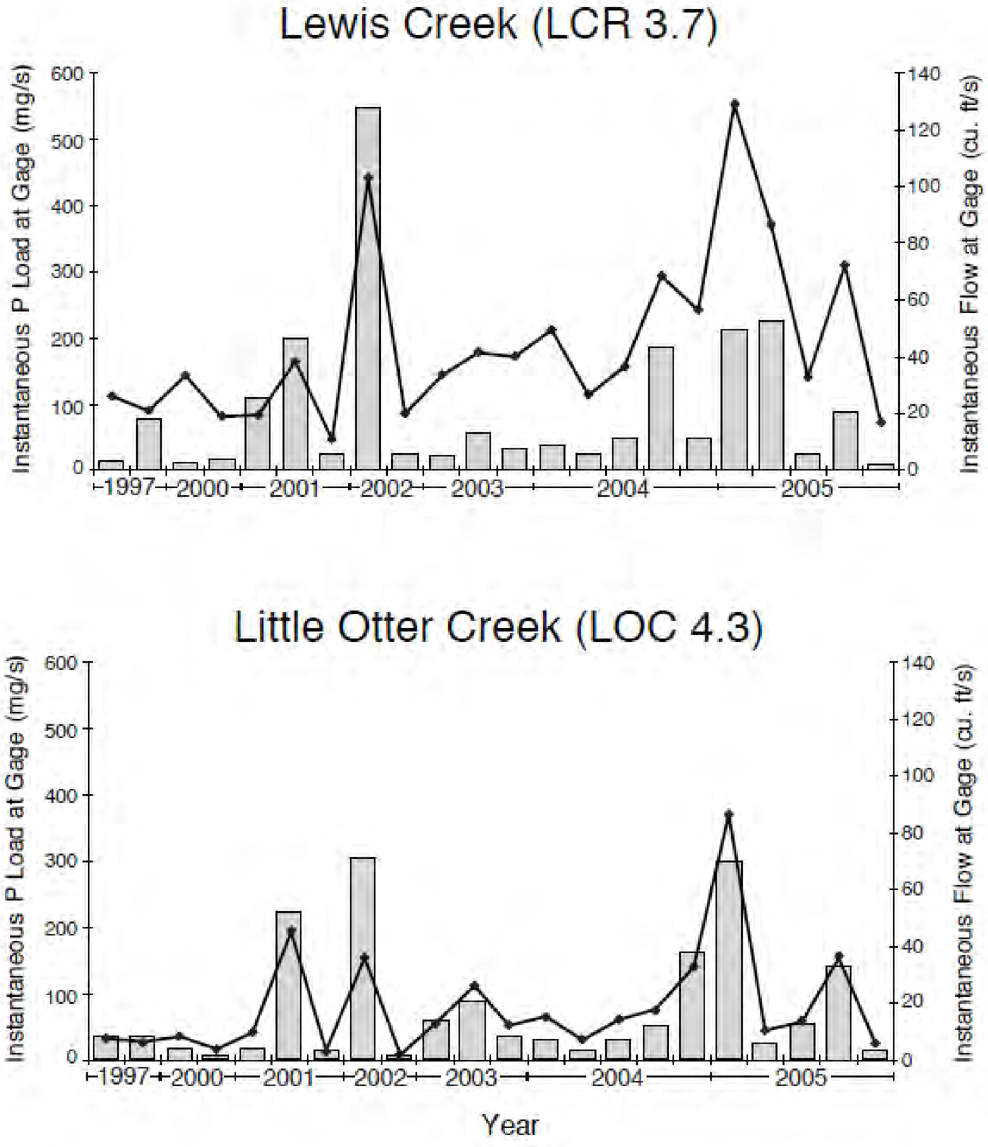

Figure 1.19. Instantaneous phosphorus loading to Lake Champlain during ACRWC sampling events at sites LCR3.7 and LOC 4.3. Sampling events were performed during the summer, low-flow months by the ACRWC to collect phosphorus concentration during the seven years shown. Mean daily flow was calculated from the instantaneous flow data from the USGS gage sites for corresponding sampling events as flow data were available. Loads were estimated by multiplying these two measures.

The relationship between flow rates and instantaneous load suggests that peak flood events in each tributary may significantly contribute to the annual phosphorus loading into Lake Champlain. The USGS National Water Information System records the peak flow events annually at each gage site. We identified phosphorus concentrations for the corresponding site and date from the records of the VT DEC Lake Champlain Long-term Monitoring Database as available. Multiplying the peak flow data and a corresponding phosphorus concentration, we calculated an estimated daily load for the day of the flood event (Tables 1.4 and 1.5).

Table 1.4. Flood events in Little Otter Creek. Peak flow events were collected at the USGS gage 04282650. Phosphorus concentrations from VT DEC Long-term Monitoring program were matched with the peak-flow events as available. Some flood events were excluded because of unavailable phosphorus concentrations for the corresponding date. Instantaneous load was derived through the multiplication of these two variables. Daily load was then extrapolated from instantaneous load.

Event	Total Phosphorus (mg/L)	Peak Flow (cu. ft/s)	Instantaneous Load (mg/s)	Estimated Daily Load (metric ton/day)	Percentage of Annual Target Load
Feb. 28, 2000	0.279	1590	12562	1.085	27.1
Apr. 10, 2001	0.155	1550	6803	0.588	14.7
Apr. 15, 2002	0.193	360	1967	0.170	4.2
Mar. 21, 2003	0.355	670	6735	0.582	14.5
Oct. 30, 2003	0.239	860	5820	0.503	12.6

Table 1.5. Flood events in Lewis Creek. Peak flow events were collected at the USGS gage 04282780. Phosphorus concentrations from VT DEC Long-term Monitoring program were matched with the peak-flow events as available. Some flood events were excluded because of unavailable phosphorus concentrations for the corresponding date. Instantaneous load was derived through the multiplication of these two variables. Daily load was then extrapolated from instantaneous load.

Event	Total Phosphorus (mg/L)	Peak Flow (cu. ft/s)	Instantaneous Load (mg/s)	Estimated Daily Load (metric ton/day)	Percentage of Annual Target Load
Feb. 28, 2000	0.341	3380	32637	2.820	72.3
Apr. 13, 2001	0.369	2750	28735	2.483	63.7
June 12, 2002	0.129	830	3032	0.262	6.7
Apr. 3, 2005	0.310	1310	11499	0.994	25.5
Apr. 16, 2007	0.202	1860	10639	0.919	23.6
Oct. 29, 2008	0.154	527	2298	0.199	5.1

Our results indicate that the single highest flow event each year contributes a considerable amount of the annual phosphorus load of each tributary into Lake Champlain. In the case of Little Otter Creek, just one day of high flow often contributes more than a quarter of the annual target load of phosphorus, with event higher percentages seen for Lewis Creek. With significant amounts of phosphorus entering Lake Champlain from Little Otter Creek and Lewis Creek, management strategies should focus on preventing excess phosphorus runoff into streams and bank erosion during flood events.

These calculations were meant to be rudimentary analyses to provide a preliminary picture of how flow rates relate to phosphorus loading in Little Otter Creek and Lewis Creek. More sophisticated calculations, such as the derivation of flow-weighted mean concentrations and the use of the FLUX method, should be performed to fully understand the relationship between flow and phosphorus loading on these tributaries. However, despite the limitations of this analysis, it is clear that the phosphorus loading into Lake Champlain from these two Addison County tributaries is significant and that the reduction of phosphorus loading during flood events should be a significant focus of watershed managers.

Final Conclusions

The overall purpose of our project was to relate phosphorus trends in Addison County's watersheds to the proposed phosphorus nutrient criteria. To this end, our group had three objectives. First, we mapped stream ecotypes in the Little Otter Creek watershed by stream reach. This is important because the recently developed criteria are dependent on ecotype, but they had not yet been mapped. Secondly, we sought to organize and analyze many years worth of nutrient data collected by citizen groups to make meaningful management recommendations and prioritize monitoring efforts. Finally, we sought to compare instream phosphorus levels to loading targets for Lake Champlain.

While the original delineation of ecotypes was primarily determined by aquatic biologists at the Department of Environmental Conservation based on biological indices, we aimed to create a preliminary methodology for determining ecotypes based on physical rather than biological attributes. We were able to delineate the reaches of Little Otter Creek and Mud Creek by ecotype.

Using the ecotype designation of Little Otter Creek we were able to determine the appropriate nutrient criteria for each ACRWC sampling site. We found that phosphorus concentrations were significantly exceeding recommended levels. Additionally, our analysis of the phosphorus concentration data for the four other watersheds—Middlebury River, Lewis Creek, New Haven River, and Lemon Fair River—led us to conclude that they often show concerning levels of phosphorus and exceed even the least restrictive nutrient criteria.

In addition to considering how phosphorus concentrations meet the instream nutrient criteria, we also analyzed how instream phosphorus concentrations relate to phosphorus loading into Lake Champlain. We found that peak flood events contribute heavily to the phosphorus load into Lake Champlain. It is evident from our results that focus should be turned to controlling the levels of phosphorus during flood events in order to meet the proposed target loads for the five watersheds studied in Addison County.

We hope that our preliminary methodology and our ACRWC data analyses will help to inform future water management efforts in Addison County by identifying appropriate nutrient criteria for stream reaches within the county and directing more focus to worrisome stream reaches and county-wide flooding events.

Appendices

Appendix 1.1. Relevant data used to assign ecotypes to the stream reaches of Little Otter Creek.

Reach Point ID	Channel Slope	Drainage Area (km^2)	Stream Order	Average Elevation (ft)	Ecotype	Notes
M04	0.0103	148.6694	4	159.5	WWMG	
T2.05	0.1530	10.1732	3	269	WWMG/ SW	reach fits for both ecotypes
M08	0.1838	102.1377	5	227.5	WWMG	
M13	0.0957	30.7577	4	333	WWMG	
M01	0.1395	187.7830	5	117.5	WWMG	elevation too low for WWMG but other values fit only for WWMG
M02	0.4095	151.8722	5	143	WWMG	
M03	0.1367	149.1735	5	157	WWMG	
T2.04	0.1431	17.9117	4	254.5	WWMG	
M07	1.1678	102.5679	5	194	WWMG/ MHG	gradient too steep for WWMG, stream order too high for MHG
M12	1.1331	31.8486	4	305.5	MHG	
M09	0.7880	92.6992	5	245	WWMG	
M10	0.0299	91.7731	2	256	WWMG	
M11	0.2260	65.9666	5	268.5	WWMG	
M14	0.0458	29.9414	2	337	WWMG/ SW	reach fits for both ecotypes
M15	0.2212	19.2192	2	349	WWMG/ SW	reach fits for both ecotypes
M16	0.9475	12.6280	1	439.5	WWMG/ SW	reach fits for both ecotypes
T2.01	0.3340	23.4931	4	170.5	WWMG	
T2.02	0.7406	22.5072	4	209.5	WWMG	
T2.03	0.1165	20.8074	4	244	WWMG	
T2.06	0.2888	6.7475	1	293	SW	
T2.07	1.0015	2.6042	2	366.5	MHG	
M05	0.0532	116.5697	1	162.5	WWMG	
M06	0.1800	111.9415	4	166.5	WWMG	

Appendix 1.2. The average phosphorus concentration and standard deviation for each sampling station per year in Middlebury River watershed.

Sampling Station	Year	Average P Conc. (mg/L)	Standard Deviation
MIR5.7	2003	0.009	0.069
MIR3	2003	0.010	0.041
MIR2	2003	0.038	0.043
MIR1.5	2003	0.053	0.027
MIR1	2003	0.053	0.004
MIR0	2003	0.066	0.002
MIR5.7	2004	0.007	0.006
MIR3	2004	0.007	0.004
MIR2	2004	0.023	0.311
MIR1.5	2004	0.159	0.007
MIR1	2004	0.022	0.002
MIR0	2004	0.024	0.002
MIR5.7	2005	0.007	0.005
MIR3	2005	0.008	2.036
MIR2	2005	0.027	0.010
MIR1.5	2005	0.938	0.004
MIR1	2005		
MIR0	2005	0.027	0.002
MIR5.7	2006	0.009	0.028
MIR3	2006		
MIR2	2006	0.038	0.028
MIR1.5	2006	0.042	0.018
MIR1	2006		
MIR0	2006	0.052	0.002
MIR5.7	2007	0.012	0.025
MIR3	2007		
MIR2	2007	0.024	0.026
MIR1.5	2007	0.032	0.018
MIR1	2007		
MIR0	2007	0.032	0.012
MIR5.7	2008	0.295	0.011
MIR3	2008		
MIR2	2008		
MIR1.5	2008	0.139	0.290
MIR1	2008		
MIR0	2008	0.027	0.861
MIR5.7	2010	0.009	0.004
MIR3	2010		

MIR2	2010		
MIR1.5	2010	0.025	0.001
MIR1	2010		
MIR0	2010		

Appendix 1.3. The average phosphorus concentration and standard deviation for each sampling station per year in New Haven River watershed.

Sampling Station	Year	Average P Conc. (mg/L)	Standard Deviation
NHR15	2003		
NHR15.5	2003		
NHR 13	2003	0.007	0.002
NHR11.5	2003	0.006	0.003
NHR10.5	2003	0.007	0.003
NHR9	2003	0.007	0.002
NHR8	2003	0.007	0.003
NHR6	2003	0.007	0.003
NHR5	2003	0.007	0.002
NHR2	2003	0.026	0.008
NHR.5	2003	0.017	0.005
NHR0	2003	0.015	0.001
NHR15.5	2004	0.007	0.002
NHR 15	2004	0.006	0.001
NHR 13	2004	0.009	0.004
NHR11.5	2004	0.008	0.004
NHR10.5	2004	0.011	0.004
NHR9	2004	0.010	0.005
NHR8	2004	0.008	0.006
NHR6	2004	0.009	0.007
NHR5	2004	0.010	0.008
NHR2	2004	0.018	0.007
NHR.5	2004	0.018	0.010
NHR0	2004	0.018	0.009
NHR15.5	2005	0.007	0.002
NHR 15	2005	0.007	0.002
NHR 13	2005	0.007	0.002
NHR11.5	2005	0.006	0.002
NHR10.5	2005	0.008	0.004

NHR9	2005	0.008	0.003
NHR8	2005	0.007	0.003
NHR6	2005	0.007	0.002
NHR5	2005	0.007	0.003
NHR2	2005	0.024	0.009
NHR.5	2005	0.013	0.004
NHR0	2005	0.012	0.003
NHR15.5	2006		
NHR 15	2006	0.009	0.003
NHR13	2006		
NHR11.5	2006	0.008	0.003
NHR10.5	2006		
NHR9	2006	0.010	0.004
NHR8	2006	0.008	0.003
NHR6	2006	0.011	0.005
NHR5	2006		
NHR2	2006		
NHR.5	2006	0.066	0.093
NHR0	2006		
NHR15.5	2007		
NHR 15	2007	0.011	0.008
NHR13	2007		
NHR11.5	2007	0.011	0.012
NHR10.5	2007		
NHR9	2007	0.013	0.017
NHR8	2007	0.022	0.022
NHR6	2007	0.015	0.019
NHR5	2007		
NHR2	2007		
NHR.5	2007		
NHR0	2007		
NHR15.5	2008		
NHR 15	2008		
NHR13	2008		
NHR11.5	2008		
NHR10.5	2008		
NHR9	2008	0.014	0.014
NHR8	2008		
NHR6	2008	0.020	0.025

NHR5	2008		
NHR2	2008		
NHR.5	2008		
NHR0	2008		
NHR15.5	2010		
NHR 15	2010	0.008	0.001
NHR13	2010		
NHR11.5	2010	0.009	0.001
NHR10.5	2010		
NHR9	2010	0.009	0.002
NHR8	2010		
NHR6	2010	0.010	0.004
NHR5	2010		
NHR2	2010	0.022	0.010
NHR.5	2010	0.015	0.009
NHR0	2010		

Appendix 1.4. The average phosphorus concentration and standard deviation for each sampling station per year in Lemon Fair River watershed.

Sampling Station	Year	Average P Conc. (mg/L)	Standard Deviation
LFB2.5	2003	0.430	0.465
LFR0	2003	0.527	0.480
LFR1.2	2003	0.538	0.189
LFR12	2003	0.445	0.289
LFR15.8	2003	0.430	0.326
LFR20.2	2003	0.743	0.393
LFR23.9	2003	0.395	0.391
LFR29.3	2003	0.360	0.145
LFR3.7	2003	0.493	0.188
LFR6.7	2003	0.530	0.251
LFT0.1	2003	0.320	0.149
LFB2.5	2004	0.084	0.077
LFR0	2004	0.187	0.141
LFR1.2	2004	0.223	0.117
LFR12	2004	0.154	0.052
LFR15.8	2004	0.116	0.042
LFR20.2	2004	0.150	0.021
LFR23.9	2004	0.090	0.052

LFR26.6	2004	0.065	0.023
LFR29.3	2004	0.063	0.011
LFR3.7	2004	0.210	0.140
LFR6.7	2004	0.236	0.163
LFT0.1	2004	0.114	0.015
LFB2.5	2005	0.099	0.081
LFR0	2005	0.162	0.079
LFR1.2	2005	0.200	0.045
LFR12	2005	0.176	0.058
LFR15.8	2005	0.099	0.053
LFR20.2	2005	0.144	0.041
LFR23.9	2005	0.055	0.014
LFR26.6	2005	0.053	0.016
LFR29.3	2005	0.097	0.012
LFR3.7	2005	0.216	0.060
LFR6.7	2005	0.262	0.099
LFT0.1	2005	0.124	0.022
LFR1.2	2006	0.280	0.084
LFR12	2006	0.316	0.093
LFR15.8	2006	0.210	0.149
LFR20.2	2006	0.238	0.129
LFR23.9	2006	0.104	0.064
LFR3.7	2006	0.337	0.113
LFR1.2	2007	0.167	0.049
LFR12	2007	0.215	0.079
LFR15.8	2007	0.062	0.024
LFR20.2	2007	0.134	0.038
LFR23.9	2007	0.055	0.027
LFR3.7	2007	0.188	0.044
LFR0	2008	0.193	0.108
LFR1.2	2008	0.206	0.095
LFR12	2008	0.164	0.069
LFR15.8	2008	0.252	0.268
LFR6.7	2008	0.251	0.111
LFB2.5	2010	0.040	0.024
LFR12	2010	0.147	0.098
LFR6.7	2010	0.129	0.085

Appendix 1.5. The average phosphorus concentration and standard deviation for each sampling station per year in Lewis Creek watershed.

Sampling Station	Year	Average P Conc. (mg/L)	Standard Deviation
LCR14	2003	0.02275	0.00818
LCR14	2004	0.0317	0.024189
LCR14	2005	0.0444	0.046333
LCR14	2006	0.0168	0.005789
LCR14	2007	0.0576	0.077033
LCR14	2008	0.032	0.027532
LCR14	2009		
LCR14	2010	0.032875	0.035454
LCR15.6	2003	0.01975	0.005852
LCR15.6	2004	0.0246	0.021524
LCR15.6	2005	0.031	0.044888
LCR15.6	2006		
LCR15.6	2007		
LCR15.6	2008		
LCR15.6	2009		
LCR15.6	2010		
LCR17.2	2003	0.00975	0.002217
LCR17.2	2004	0.0136	0.009236
LCR17.2	2005	0.0166	0.012954
LCR17.2	2006	0.0104	0.002881
LCR17.2	2007	0.0286	0.032161
LCR17.2	2008	0.020833	0.024863
LCR17.2	2009		
LCR17.2	2010		
LCR18.6	2003		
LCR18.6	2004		
LCR18.6	2005		
LCR18.6	2006		
LCR18.6	2007		
LCR18.6	2008	0.017667	0.015858
LCR18.6	2009		
LCR18.6	2010		
LCR19.5	2003	0.009	0.003464
LCR19.5	2004	0.013111	0.008738
LCR19.5	2005	0.0209	0.024875
LCR19.5	2006	0.0134	0.006586
LCR19.5	2007	0.0244	0.023301

LCR19.5	2008	0.014667	0.01353
LCR19.5	2009		
LCR19.5	2010		
LCR3.7	2003	0.03975	0.015966
LCR3.7	2004	0.0489	0.044396
LCR3.7	2005	0.0752	0.081464
LCR3.7	2006	0.0172	0.00502
LCR3.7	2007	0.0624	0.037766
LCR3.7	2008		
LCR3.7	2009		
LCR3.7	2010	0.032875	0.015551
LCR7.25	2003		
LCR7.25	2004		
LCR7.25	2005		
LCR7.25	2006		
LCR7.25	2007		
LCR7.25	2008		
LCR7.25	2009		
LCR7.25	2010		
LCR7.25	2008	0.041833	0.040216
LCR7.25	2009		
LCR7.25	2010		
LCR9.9	2003	0.0435	0.00995
LCR9.9	2004	0.0554	0.031413
LCR9.9	2005	0.053	0.017507
LCR9.9	2006	0.0578	0.015482
LCR9.9	2007	0.0894	0.141661
LCR9.9	2008	0.052833	0.052686
LCR9.9	2009		
LCR9.9	2010		

Appendix 1.6. The average phosphorus concentration and standard deviation for each sampling station per year in Little Otter Creek watershed.

Sampling Station	Year	Average P. Conc (mg/L)	Standard Deviation
LOC14.4	1997	0.095667	0.005132
LOC4.3	1997	0.1625	0.022174
LOC7.8	1997	0.2275	0.045735
LOC14.4	1998	0.1735	0.071323
LOC4.3	1998	0.23025	0.11642

LOC7.8	1998	0.1675	0.041741
LOC14.4	1999	0.087	0.041601
LOC4.3	1999	0.07575	0.025747
LOC7.8	1999	0.18	0.061487
LOC14.4	2000	0.096	0.066718
LOC4.3	2000	0.072	0.006
LOC7.8	2000	0.0955	0.013478
LOC14.4	2001	0.118	0.062145
LOC4.3	2001	0.11625	0.064999
LOC7.8	2001	0.1345	0.076483
LOC14.4	2002	0.084	0.041737
LOC4.3	2002	0.15775	0.105554
LOC7.8	2002	0.16375	0.020614
LOC14.4	2003	0.07775	0.01841
LOC4.3	2003	0.12325	0.03169
LOC7.8	2003	0.14225	0.015966
LOCNEW	2003	0.1035	0.020339
LOC14.4	2004	0.0572	0.023264
LOC7.8	2004	0.0736	0.029912
LOCNEW	2004	0.0802	0.016146
LOC14.4	2005	0.0715	0.026
LOC4.3	2005	0.121	0.039686
LOC7.8	2005	0.095	0.02512
LOCNEW	2005	0.096	0.027559
LOC11	2006	0.1732	0.054159
LOC14.4	2006	0.090167	0.043489
LOC4.3	2006	0.279	0.163401
LOC7.8	2006	0.198833	0.180882
LOC11	2007	0.0832	0.028499
LOC14.4	2007	0.062333	0.028996
LOC4.3	2007	0.0954	0.111204
LOC7.8	2007	0.0406	0.011433
LOC11	2008	0.1094	0.051558
LOC14.4	2008	0.07225	0.033673
LOC4.3	2008	0.0962	0.075732
LOC7.8	2008	0.1034	0.046391
LOC10	2010	0.119167	0.14457
LOC11	2010		
LOC14.4	2010	0.0764	0.247504
LOC7.8	2010	0.12875	0.130786
LOC8	2010	0.10025	0.068785

Appendix 1.7. Instantaneous phosphorus loads during ACRWC sample events. Sampling events were performed during the summer, low-flow months by the ACRWC to determine phosphorus concentration. Mean daily flow was calculated from the instantaneous flow data from the USGS gage sites. Standard deviation from the calculations is shown in brackets. Loads were estimated by multiplying these two measures.

	LCR 3.7		LOC 4.3	
Date of Sample	Mean Daily Flow (cu. ft/s)	Instantaneous Load (mg/s)	Mean Daily Flow (cu. ft/s)	Instantaneous Load (mg/s)
July 12, 1997	26.12 [1.36]	14.80	6.99 [0.80]	33.63
July 26. 1997	21.05 [0.22]	77.50	6.25 [0.76]	33.64
June 28, 2000	33.45 [1.72]	12.31	7.05 [0.47]	15.58
July 15, 2000	19.06 [1.41]	16.19	3.32 [0.37]	6.76
June 27, 2001	19.48 [0.66]	110.32	9.20 [0.39]	16.41
July 14, 2001	38.25 [0.56]	199.29	45.28 [6.16]	221.82
Aug. 11, 2001	11.03 [0.84]	24.99	2.90 [0.08]	14.11
June 29, 2002	102.97 [13.63]	548.16	35.73 [4.75]	305.57
July 27, 2002	20.11 0.32]	25.63	1.97 [0.06]	5.02
June 25, 2002	33.62 [0.78]	22.84	12.37 [0.56]	59.20
July 23, 2002	41.62 [3.22]	56.55	26.70 [1.98]	89.22
Aug. 6, 2002	40.09 [1.93]	32.92	11.07 [0.45]	34.16
June 23, 2003	49.35 [2.80]	37.73	14.26 [0.82]	29.47
July 7, 2003	26.68 [1.94]	23.42	6.81 [0.58]	15.43
July 21, 2003	36.51 [4.23]	47.55	12.77 [1.02]	29.30
Aug. 4, 2003	68.36 [10.25]	187.77	16.99 [3.26]	49.55

Aug. 18, 2003	56.51 [3.99]	49.60	35.73 [1.93]	160.88
June 22, 2004	128.83 [8.36]	211.60	87.93 [14.47]	298.78
July 6, 2004	86.46 [9.81]	225.25	9.66 [0.47]	24.08
July 20, 2004	32.81 [1.40]	24.16	12.27 [0.94]	52.46
Aug. 3, 2004	72.18 [10.47]	89.93	36.76 [4.46]	141.58
Aug. 17, 2004	16.84 [0.95]	10.96	5.30 [0.68]	11.40

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Chapter 2. Roadside Ditches

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Introduction

Lake Champlain has suffered from eutrophication for many years, a problem which has only increased with time and which has not yet been successfully controlled. The lake is bordered by two states, New York and Vermont, and the province of Quebec in Canada. Eutrophication is the "bloom" or massive increase in phytoplankton in a water body, caused by an increase in nitrites and particularly phosphates. The harmful effects of eutrophication include deoxygenation of water, fish die-offs, toxicity to humans and other species, and foul smells. Phosphorus loading refers to the input of phosphorus into the water body, here Lake Champlain, and encompasses all sources of phosphorus including runoff from towns, cities, agricultural land, sewage outputs, and others. One of the most significant sources of phosphorus in Vermont is runoff from roads and the land bordering roads. The runoff enters roadside ditches, which lead into brooks, streams, and rivers that eventually flow into Lake Champlain. However, despite their known contribution of untreated runoff to the watershed and thereby to Lake Champlain, no studies have been done to quantify the phosphorus load conveyed by roadside ditches.

Ditches are a key source to take into account when considering the causes of the eutrophication threatening Lake Champlain. Ditch networks surround many of the roads in Vermont, as one major purpose of ditches is to prevent road erosion. Ditches lined with grasses or rocks may help reduce phosphorus loading by trapping sediment that carries phosphorus and by slowing the velocity of flowing water, allowing sediment to settle out and reducing erosion, but unmanaged ditches have the potential to become stream channels: conduits into streams, rivers, and then Lake Champlain. In general, roadside ditches play a more important role in road infrastructure maintenance than in mitigating pollution. Even when they successfully catch runoff flowing overland from fields and surrounding land, directing it away from the road surface, ditches that are not properly managed cannot effectively trap phosphorus laden sediment and water.

Road erosion contributes heavily to sediment loading in ditches (and therefore in streams). Sediment loading is often highest during storm events, snowmelt in the spring, or directly after road construction work – times when there is higher water flow than usual or when the road surface has been disturbed. In order to prevent excessive erosion of the road surface, roads must be built to shed water not only during normal runoff events, but also during large flooding events. Road erosion features are often indicators of poor water-runoff management. Early indicators include rills, which if unrepaired may turn into gullies. Bank erosion, sheet erosion, and in severe cases, entire streams crossing the road are also clear signs that a road has water drainage problems. Proper road construction can help prevent erosion. A few of the main protective measures include ditches to channel runoff; turnouts, which periodically allow ditch water to infiltrate vegetation or be redirected into a stream; crowned roads that allow water to flow towards the ditches rather than accumulate on the road; water bars, which are dips in the road that prevent sheet erosion by slowing and diverting water flow; and culverts, which channel flowing water under roads or beneath obstacles.

Ditches come in a variety of shapes, structures, and degrees of repair. Some are well-maintained, free of debris, possibly rock-lined or vegetated to slow water flow, catch sediment and help the ground absorb water. Others turn out often into vegetation to prevent water from picking up too much velocity (fast-moving water is more likely to carry large amounts of sediment and less likely to absorb into the ground over which it travels). Blocked or improperly structured ditches cause fast-flowing water to scour away or undercut banks, contributing to the transportation of suspended sediment and any attached phosphorus. Similarly, culverts can be poorly maintained (blocked by branches, for example, or built too small for the flow of water that must go through it) which can result in erosion right below the mouth of the culvert from water flowing at speed into the ground, picking up sediment and potentially destabilizing the culvert structure.

In order to understand why a ditch is or is not successfully channeling water, it is important to lay out what makes a ditch good or poor. Ditches are meant to divert runoff from roads and nearby landscapes in an efficient way that prevents road erosion and limits the amount of sediment that is carried in runoff. In order to accomplish those two tasks, a ditch must be well shaped – not too steeply sided nor too shallow – and be lined with proper vegetation or rocks. If a ditch is well lined with vegetation or rocks, it will be able to filter sediment that is carrying phosphorus out of the flowing water before it reaches larger bodies of water. An ideally functioning ditch should be about two feet wide and be able to hold about 2 cubic feet of water (NRCS Better Backroads Manual, 2011). If a ditch is lined with grass, its sides should have less than 5% slope. If a ditch is lined with rock, its side should have more than a 5% slope. If ditches are shaped and lined correctly, they should be able to divert water away from roads and into vegetated areas, and there should be no standing water where they empty. A "good" ditch, exhibiting all the qualities just listed, will not only reduce phosphorus loading into Lake Champlain, but will also save local municipalities the money used on repairing "poor" ditches and the road erosion they cause. Our study is intended to survey the existing ditch network in one Addison county watershed, creating a model based in one small watershed that will assist watershed managers in quantifying this very important source of phosphorus loading. We will also create a pilot typology of roadside ditches, recognizing their dual role in maintaining infrastructure and in channeling water and phosphorus, which can be used by towns in planning road maintenance.

Background: The Little Otter Creek Watershed

The Little Otter Creek watershed provides an opportunity to study a small-scale system containing different landuse types, soil types, slopes, and road types, all of which contribute significantly to the high levels of phosphorus in this region. The watershed passes through four towns, Bristol, New Haven, Monkton, and Ferrisburgh, with the city of Vergennes located nearby (Fig. 2.1). In addition, with agricultural land covering 52% of the watershed (Fig. 2.2), and naturally phosphorus rich glacio-lacustrine deposits making up over 90% of the soil cover, phosphorus runoff is a real concern (ACRC 1991-2008, p. 6-7).The state of Vermont established a limit of 0.014 mg/l of phosphorus for the section of Lake Champlain directly impacted by the Little Otter Creek watershed (ACRC 1991-2008, p. 20). However, this watershed has traditionally shown moderate to high levels of phosphorus exceeding the proposed criteria, evident in tests performed by the citizen-run River Watch Collaborative (Miner 2010; Chapter 1 of this report, Fig. 1.3). These measurements also show that 56% of the phosphorus measured in the Little Otter Creek watershed is in its dissolved form, likely a result of agricultural or municipal runoff
(ACRC 1991-2008 p 23).

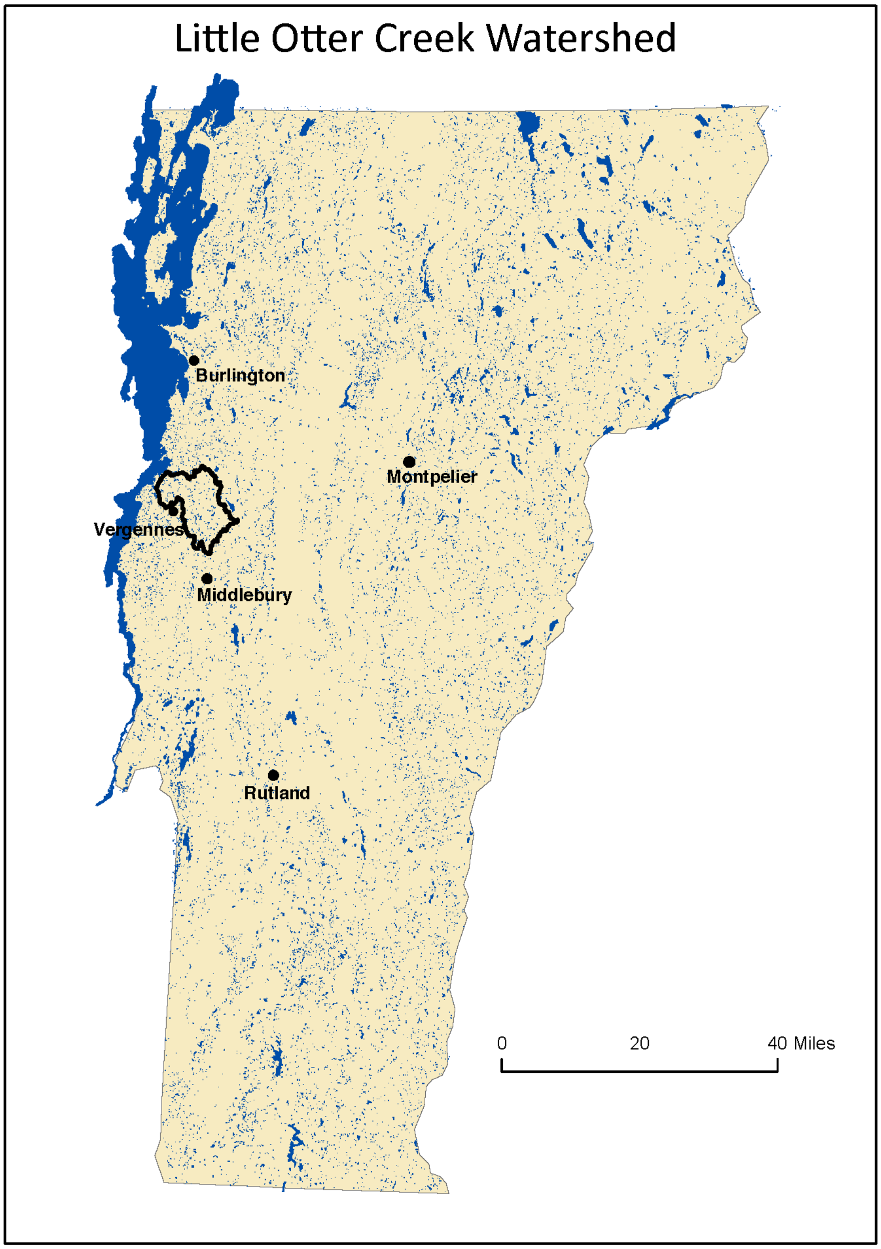


Figure 2.1. This map of the Little Otter Creek (LOC) watershed shows the watershed in relation to other water bodies and major cities in the state. Located on the southeast edge of Lake Champlain, the LOC drains directly into the southern shallow section of the lake.

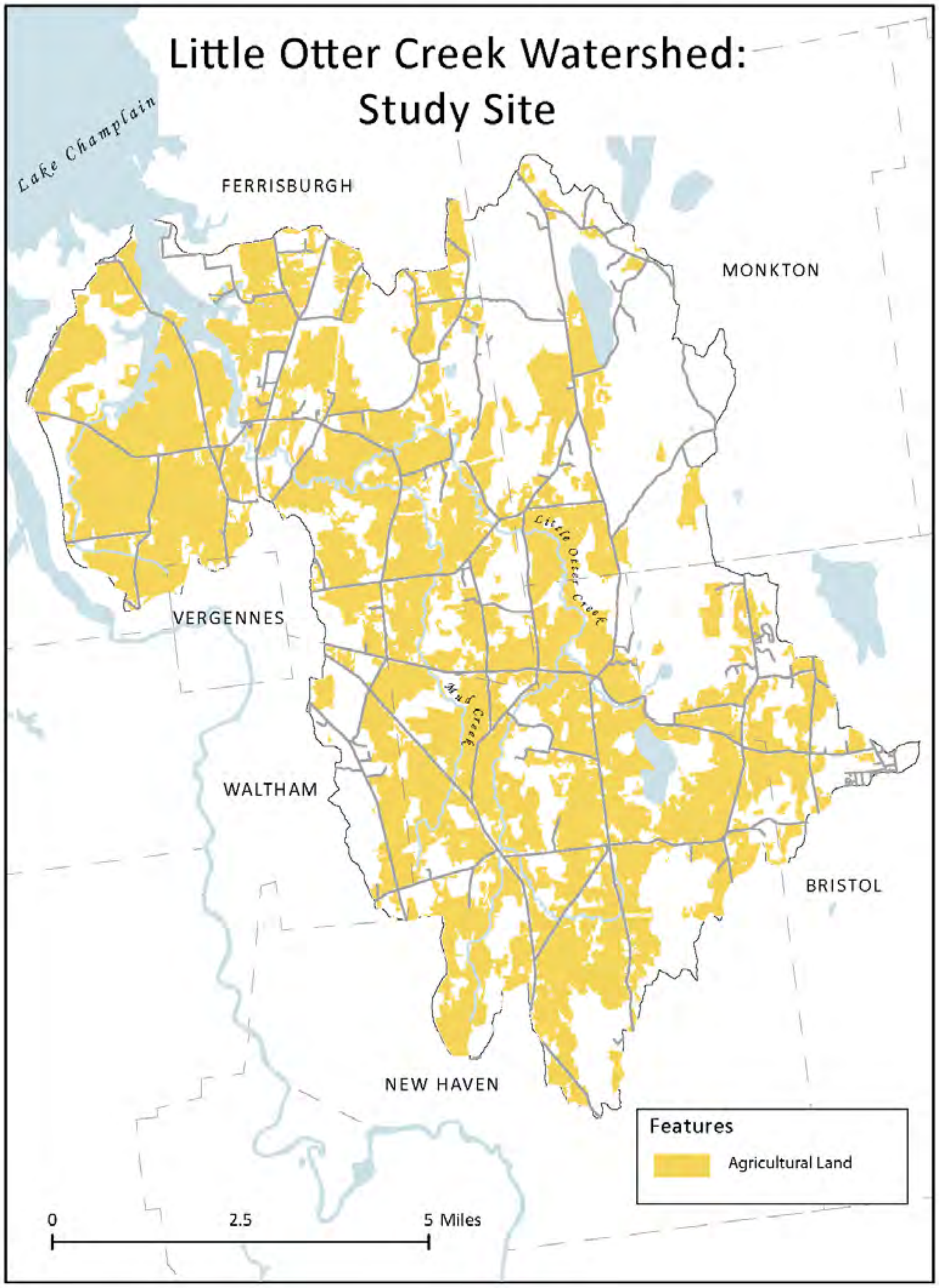


Figure 2.2. This map shows a closer view of the LOC watershed with an overlay of agricultural land. There is a clear interaction between the road network, stream network, agricultural lands, and Lake Champlain.

Despite the availability of figures regarding total watershed phosphorus load, the amount of phosphorus contributed to the system by roads and roadside ditches is relatively unknown as the system of ditches, culverts, and potentially existing erosion features have not been inventoried. Class 2 and 3 roads, unpaved but relatively well maintained, are the most common within the Little Otter Creek watershed. These roads and their associated infrastructure likely contribute significantly to the phosphorus-laden runoff, not only because their oft traveled, unpaved surfaces are susceptible to erosion, but also because the very infrastructure designed to protect roads from erosion effectively serves as a direct conduit of runoff from the roads and the entire landscape into nearby stream networks. By inventorying ditches, culverts, and runoff features, one can gain a better understanding of the amount of sediment and phosphorus added by road and ditch networks into the Little Otter Creek watershed.

Methods

1. *Surveys of all Class 2 and 3 roads in the Little Otter Creek watershed to compile data on where existing ditches are located.*

A large-scale map of the study area was selected to use for the surveying task. To be useful for this surveying study, the map must cover a road network that is accessible in terms of distance and compatible with the terms of the study (that is, primary Class 2 and 3 roads). The map should include topography, landuse/land cover, water bodies, and roads. A color coordinated key was made specifically for use with our map, using colors and symbols to correlate with good ditches, poor ditches, buffer zones, steeply sloped road sections, culverts and water bodies that are unmarked on the basemap. Two or more members of our group then drove each road segment and surveyed the sides of the roads for the ditches. The driver or a passenger on the driver's side of the car is responsible for the left side of the road, while the right-side passenger is responsible for the right side of the road and for marking each ditch and feature on the map as the survey goes forward. It is very important for the mapper to note the direction in which they are traveling and be aware of direction of travel, as it can be easy to get turned around or confuse directions and mark ditches and features incorrectly, or transpose them to the wrong side of the road.

2. *Surveys to classify the quality of the existing ditches (good or poor) and whether buffering exists between the ditch and the landscape*

This occurs simultaneously with the methodology described in Section 3.1. This type of survey work is a group effort and cannot be completed effectively without at least two and optimally three group members in each car. All persons in the car must be observing features of ditches, buffers, road surfaces and the surrounding landscape as well as notifying the designated mapper of those features. On most class 2 and 3 roads, it is possible to drive quite slowly, as these roads are frequently sparsely trafficked, and in this situation all surveyors can discuss the qualities of each ditch segment and whether it should be designated "good" or "poor" before the mapper transfers these data onto the map. It can also be useful to photograph interesting ditch or road features, as these can be helpful when transferring the hand-mapped data to a computer mapping program for analysis.

3. *Analysis of collected survey data and existing data to create maps illustrating location of ditches, classification thereof, location of buffers wherever present, and stream networks all overlaying the existing data on Class 2 and 3 roads.*

Our first goal for this methodology was to build a map that would illustrate the location of ditches, classification thereof, location of buffers wherever present, and stream networks all overlaying the existing data on Class 2 and 3 roads. Using ArcGIS, we created a map containing all of the surveyed ditches and buffers and added this to the existing road, culvert, landuse/land cover, geologic, and hydrologic data available from the Vermont Center for Geographic Information. With this data we were able to calculate the total miles of ditches in comparison to the road network, stream network, and buffer network.

Next, we created additional maps that illustrate ground cover, slope, soil type and stream flow. Using the enhanced basemap created in the first part of this mapping analysis, we performed analyses involving land use, slope, soil type, and proximity to the water network to determine the relationship between these variables. The goal of this mapping is to determine the amount of ditching that occurs on agricultural land, steep slopes, and erodible soil close to the hydrologic network. These maps will provide in-depth information for each site and for the watershed in general. They will also allow for comparisons to be made between different sites, areas and features.

4. *Site analysis of four poorly maintained and two well maintained sites to gain a better understanding of the characteristics of successful and unsuccessful ditches.*

An analysis was performed by studying each of the features such as ditch quality, culvert repair, width and quality of buffer, repair of road surface, and so on. Each category was examined individually and in conjunction with all other categories in relation to each other. Based on these multi-criteria evaluations, four sites were selected as exemplars of the worst conditions seen during this survey. In addition, two sites that exhibit the most successful and well-maintained ditch conditions that we observed were selected as model "good ditches." These six sites were used for case studies.

5. *Site analysis of the ditches selected in method 4 by collecting quantitative data on ditch width, height, slope, soil type, erosion features, surrounding land cover and proximity to bodies of water.*

This in-depth site analysis was conducted at each of the six sites (both "good" and "poor" sites). There are six criteria to be applied. First, ditch width was determined by measuring the distance between ditch banks. Height was determined by measuring the distance from the base of the ditch trough to the height of the ditch bank. Erosion features were quantified through visual descriptions of the road and the banks of the ditch such as: "minimal erosion" or "highly eroded." Land cover was assessed to see if it correlates with a GIS land cover dataset from the Vermont Center for Geographic Information (VCGI). Surrounding bodies of water, streams, rivers, lakes and wetlands are all noted.

6. *Analysis and extrapolation. From examined sites, we created suggestions for additional sites in need of remediation within the watershed and explained how our methodology can be replicated for further studies.*

The goal of the site analysis was to produce clear visual data showing the most noticeable and common characteristics of poor ditches and how those features interact with the surrounding landscape features. The good ditch analysis provides prototypes, in order to give municipal planning departments a standard to work towards for developing and maintaining highly functional ditches. The site analysis also identifies priority sites ideal for remediation within the Little Otter Creek watershed, and for our methodology to be replicated in other watersheds throughout Vermont and elsewhere.

Results

1. Little Otter Creek Watershed Survey

The Little Otter Creek watershed is located in west-central Vermont (Fig. 2.1), and has direct outflow into Lake Champlain (Fig. 2.2). There are approximately 90 miles of Class 2 and 3 roads in the Little Otter Creek watershed. About 76 miles of ditch network, associated with the existing road network, was surveyed in our study. 84% of roads had a ditch on one or both sides of the road (Fig. 2.3).

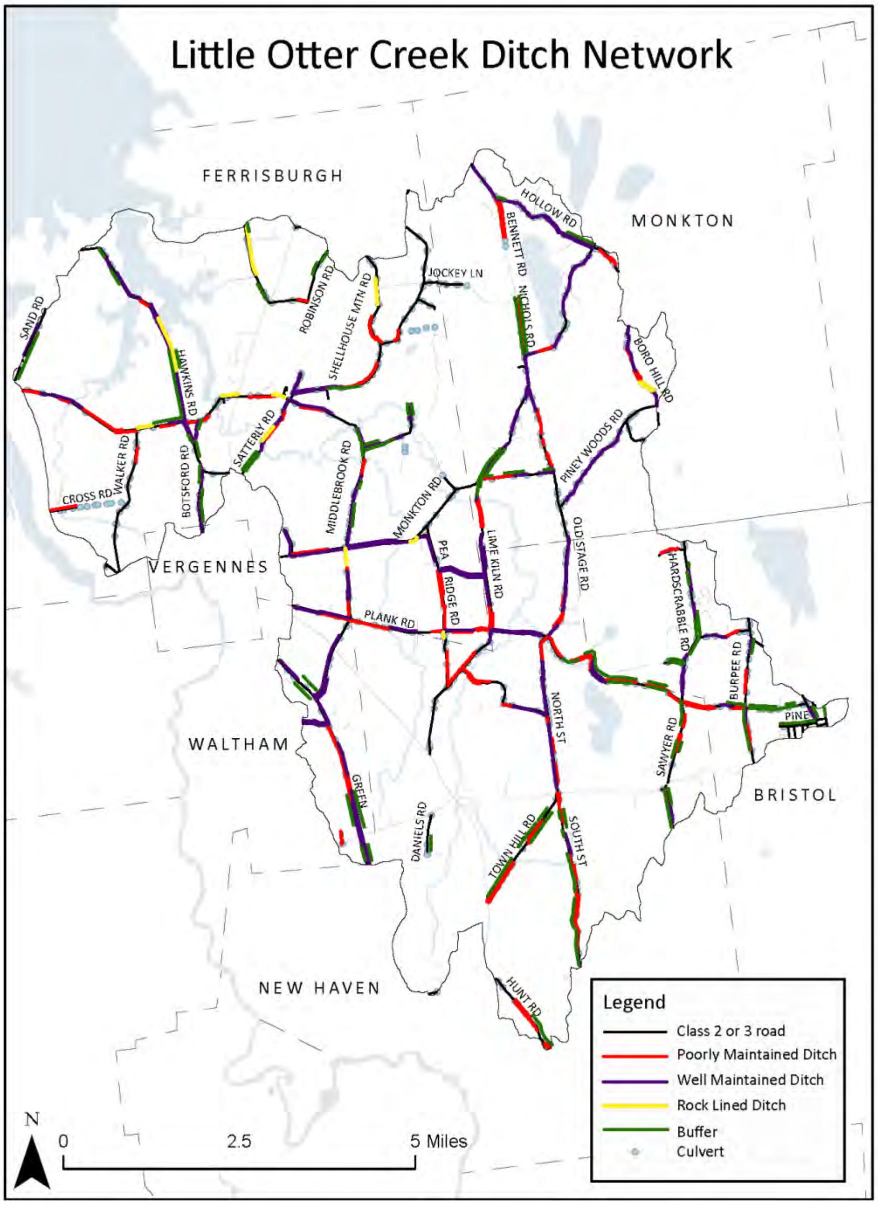


Figure 2.3. This map is the result of our survey of the Class 2 and 3 road network, including all the ditches—classified by quality—and buffers. From this map we used Arc GIS to calculate the number of ditches and quantify their interactions with the watershed to help determine their contribution to phosphorus loading.

Within that ditch network, 61%, or 46 miles, were defined by our study as well-maintained ditches (includes 3.5 miles of remediated rock-lined ditches), and 39%, or 30 miles, were defined as badly-maintained ditches. Of all the roads with ditches (well- or badly-maintained), 33% have vegetated buffers, leaving only 25 miles of road with buffers between the surrounding landscape and the ditch. As a result, there remain many miles of poorly-maintained ditches that do not have a buffer system, vegetation or any kind of rock lining to slow or filter phosphorus-laden water. This last and worst-maintained category of ditches cannot in any significant way prevent suspended sediments in the water from entering the stream network and contributing to phosphorus loading in Lake Champlain.

Ditches cross the stream network in the Little Otter Creek watershed about 270 times, with many of these crossings flowing through culverts (Fig. 2.4). The smaller streams all flow into either the Mud Creek or the Little Otter Creek, which eventually merge into one river feeding Lake Champlain. The 76 miles of ditch network, a previously unmapped and unaccounted for source of phosphorus loading, increase the stream network density by 6.5%. In some cases, there are large areas of wetlands that intersect streams and provide a filtration system for ditch runoff. Notably, there is a large wetland system located directly at the mouth of the Little Otter River as it enters Lake Champlain.

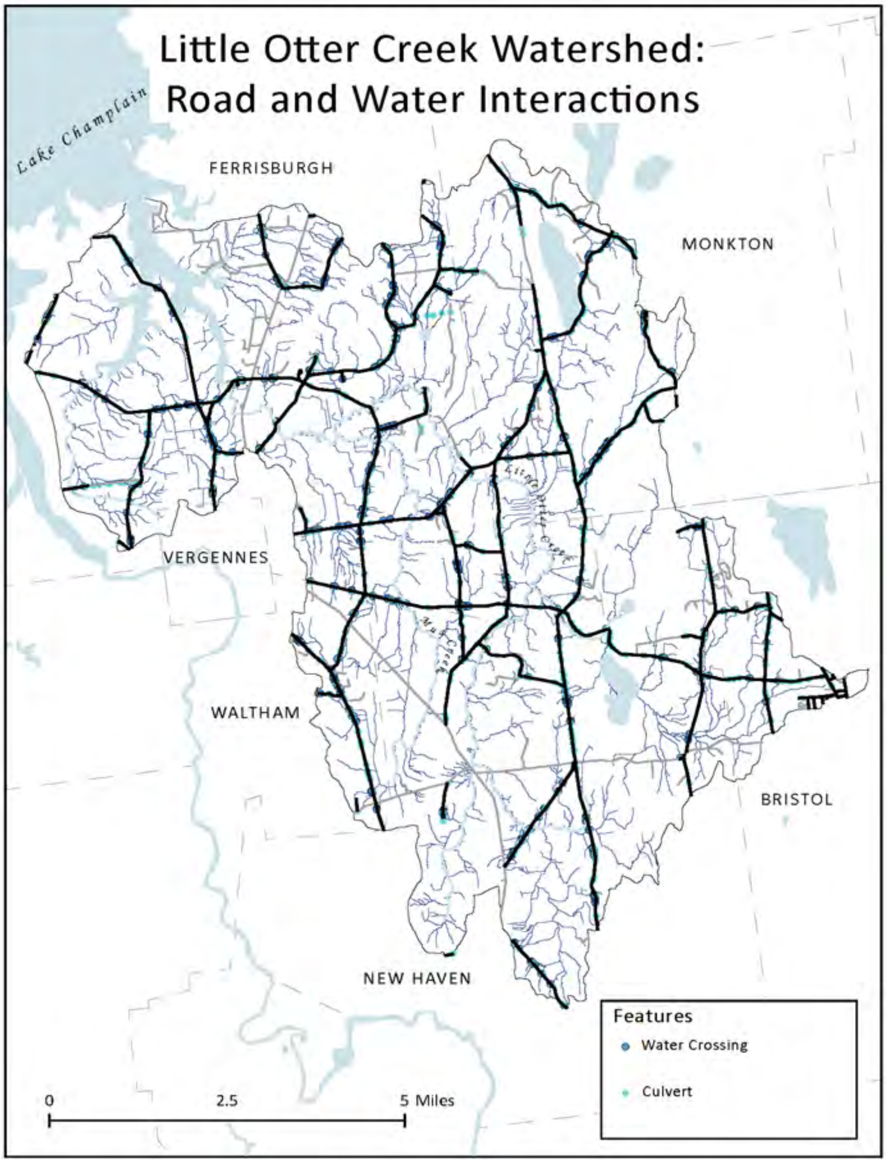


Figure 2.4. A map showing the interactions between the road and stream networks in the LOC watershed.

This wetland area provides an invaluable filtration service by capturing sediment and absorbing phosphorus. However, other wetland areas intersecting the streams and roads are much smaller and less able to filter the ditch runoff. There are only five or six other locations with small wetland areas, mostly located farther up the stream network, where the water is less likely to be carrying a significant accumulated phosphorus load in the first place.

Over 80% of all the poorly-maintained ditches (working out to about 25 miles or 30% of all ditches) in the watershed were located directly next to agricultural lands (Fig. 2.5a). Of these ditches next to agricultural lands, 70% had no vegetated buffers separating the ditches from the land. This may have implications for phosphorus loading because soils without vegetation are less protected, more erodible, and often contain more phosphorus from farming inputs such as fertilizer and manure. In addition, 95% of poorly maintained ditches are located on "highly erodible" or "potentially highly erodible" soils, as classified by the National Resource Conservation Service (Figure 2.5b). Similarly, if the agricultural lands map is compared with the erodible soils map, there are numerous locations where agricultural and highly erodible soils intersect (Fig. 2.5c). Highly erodible soils are determined by the factors of rainfall, slope, and susceptibility of soil-type (physical and chemical properties of the soil).

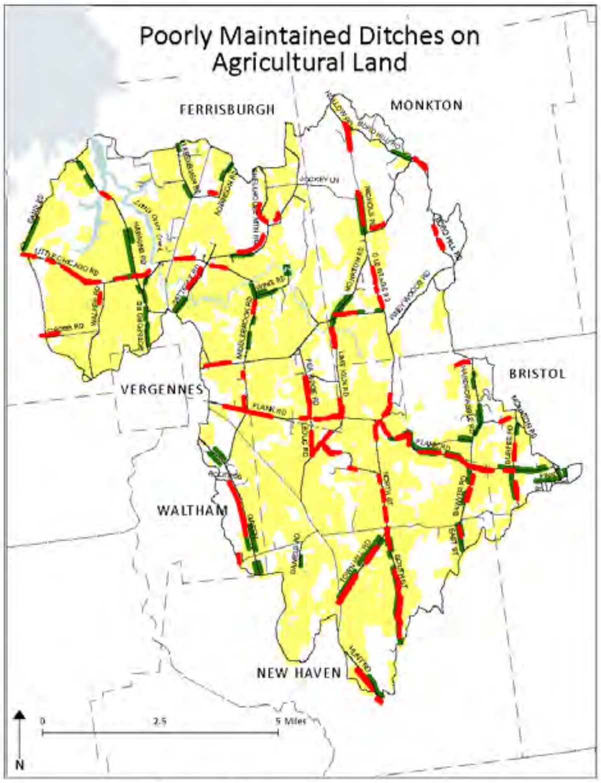


Figure 2.5a

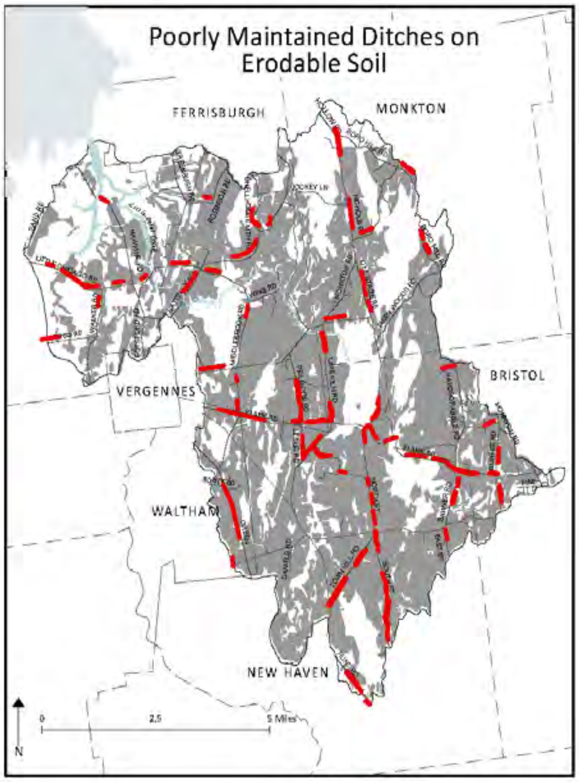


Figure 2.5b

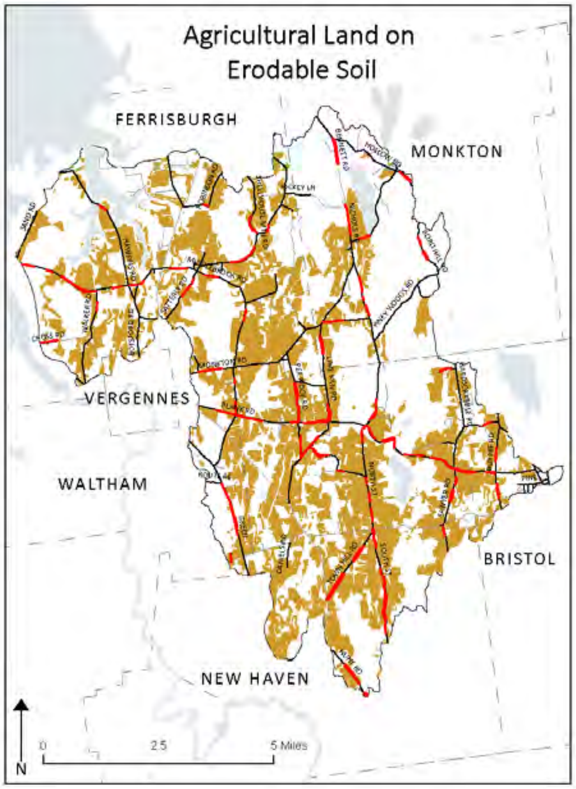


Figure 2.5c

Figure 2.5a. Over 80% of poorly maintained ditches (equally about 25 miles of ditching) are on agricultural lands. About 70% of these ditches do not have a buffer separating them from agricultural land. **Figure 2.5b.** About 95% of poorly maintained ditches are located on soil classified as "highly erodible" or "potentially highly erodible by the NRCS. **Figure 2.5c.** A significant amount of agricultural land intersects with erodible soils, highlighting sites where ditch remediation could be most useful.

Comparing the ditch network survey with an analysis of slope was another way to assess the potential erodibility and phosphorus loading of an area (Fig. 2.6). Almost 50% of the poorly maintained ditches were located on slopes >5%. About 15% of these ditches were located on steep slopes (>10%), especially those in the northeast section of the watershed. Roads with steep grades need to have regularly maintained (ideally rock-lined) ditches because runoff water picks up more power and sediment during rain events in these steeply sloping areas.

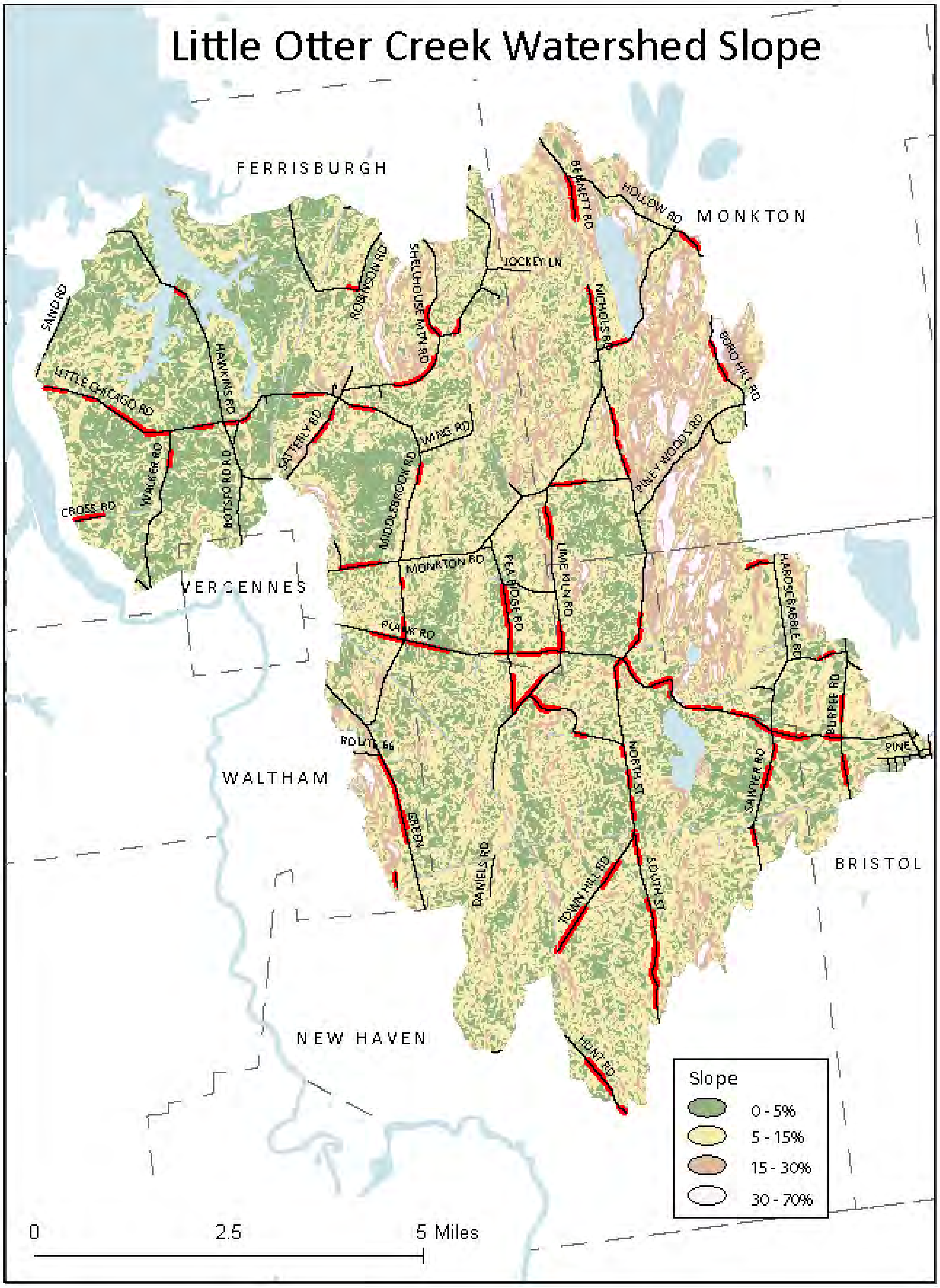
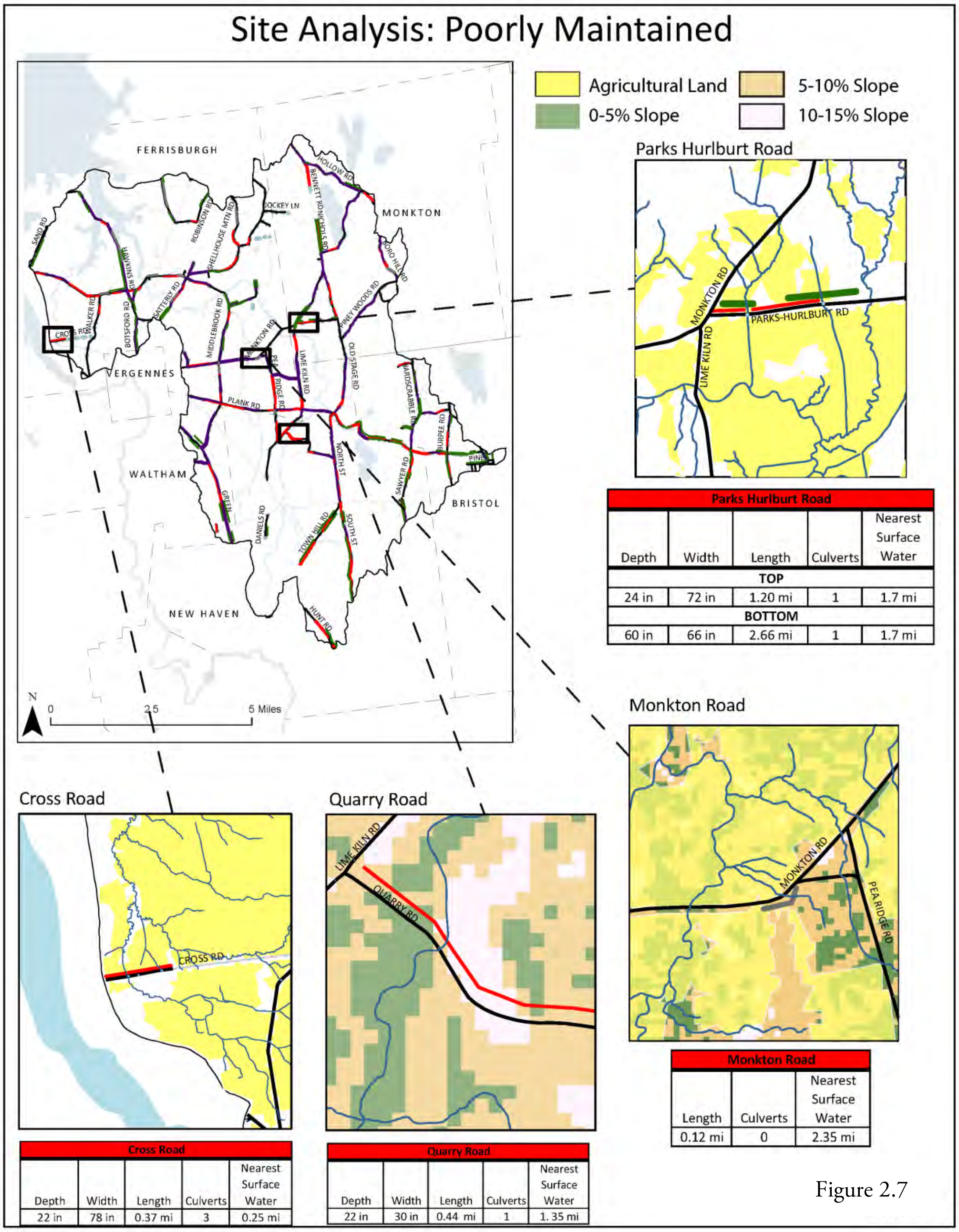


Figure 2.6. Roughly half of the poorly maintained ditches are located on steep slopes, especially in the northeast corner of the watershed where the Green Mountains Rise out of the Champlain Valley.

After completing the general survey of the entire area of the Little Otter Creek watershed, several example sites were selected to fully demonstrate the types of "poorly maintained" and "well-maintained" ditches and their effects on the landscape. Four sites were selected for poor maintenance (Fig. 2.7), and two example sites were selected for good maintenance (Fig. 2.8).



Parks Hurlburt Road

Depth	Width	Length	Culverts	Nearest Surface Water
TOP				
24 in	72 in	1.20 mi	1	1.7 mi
BOTTOM				
60 in	66 in	2.66 mi	1	1.7 mi

Monkton Road

Length	Culverts	Nearest Surface Water
0.12 mi	0	2.35 mi

Cross Road

Depth	Width	Length	Culverts	Nearest Surface Water
22 in	78 in	0.37 mi	3	0.25 mi

Quarry Road

Depth	Width	Length	Culverts	Nearest Surface Water
22 in	30 in	0.44 mi	1	1. 35 mi

Figure 2.7

Figure 2.7 shows the four poorly maintained sites chosen to analyze further. Factors such as slope, landuse, and physical characteristics influence the ability of these ditches to adequately control phosphorus runoff. Figure 2.8 shows the two ditches selected to illustrate well maintained ditches. They are good examples of vegetated and rock-lined ditches, the two most accepted ways to reduce erosion and trap phosphorus in runoff.

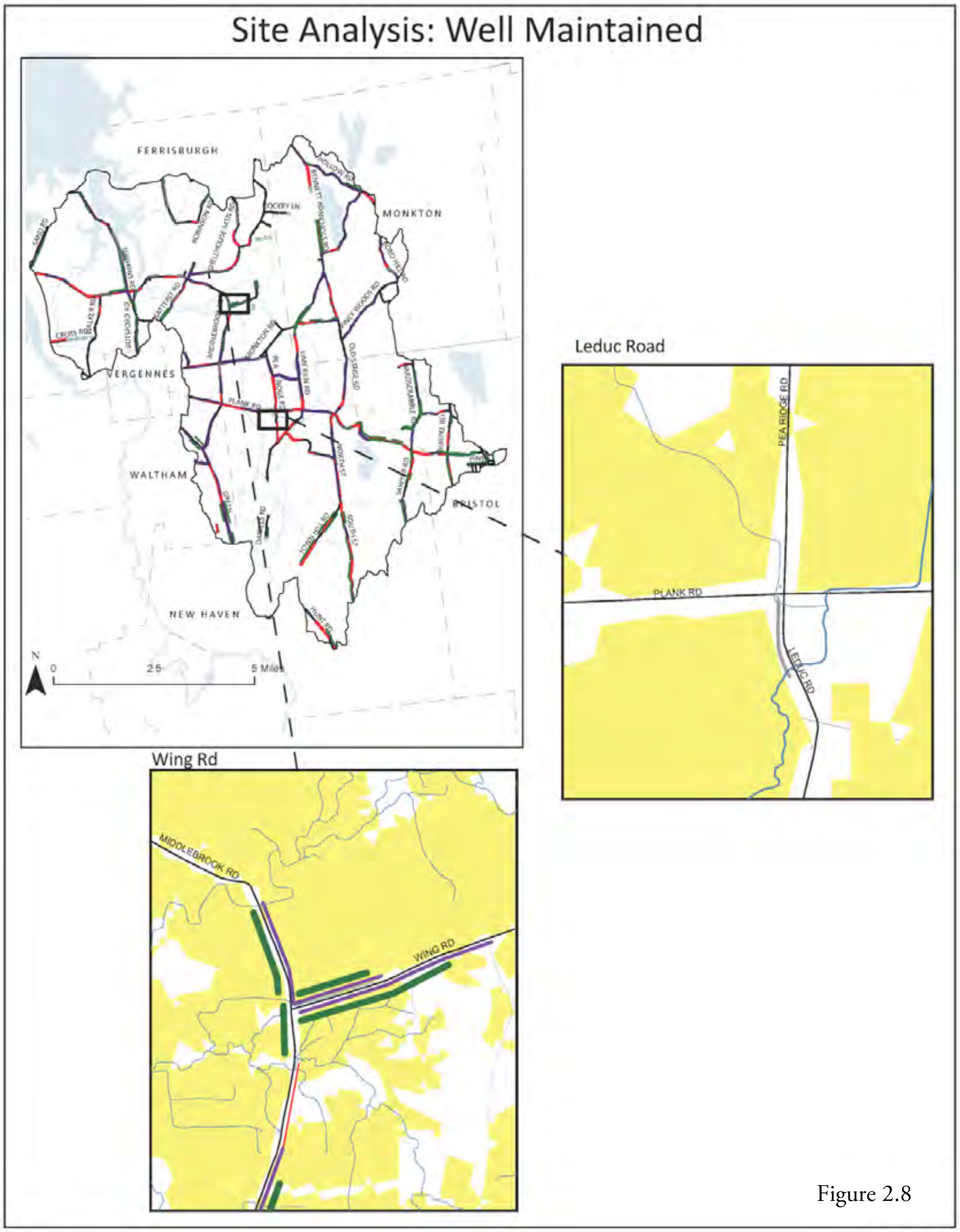


Figure 2.8

“Poorly Maintained” Site Studies

Site 1 was located on Cross Road, at the western edge of the watershed and located approximately 3 miles from Lake Champlain. At this site, agricultural fields drained directly into a ditch network on the southern side of the road with no buffer, and rills were forming in the agricultural field as sediment-laden water was draining into the ditch (Fig. 2.9). The ditch was 22 inches deep and 78 inches wide, making the depth to width ratio approximately 1 : 3.5, and the length of the ditch extended over half a mile. The smaller the depth to width ratio of a ditch is, the slower the water will flow, helping to prevent the erosion of sediment. A 30-inch diameter culvert carried this water under the road, through a small vegetated patch, and into a larger ditch located in a field that carried the water into the main river system. Further along the road, there were a large number of uprooted trees in standing water (Fig. 2.10). Some trees had obviously been uprooted a few years ago, whereas others had recently fallen. Combined with the evidence of standing water, these factors pointed towards issues with water-logged soils and poor drainage. At this site, we strongly recommend both drainage improvement and vegetated buffers next to the field.

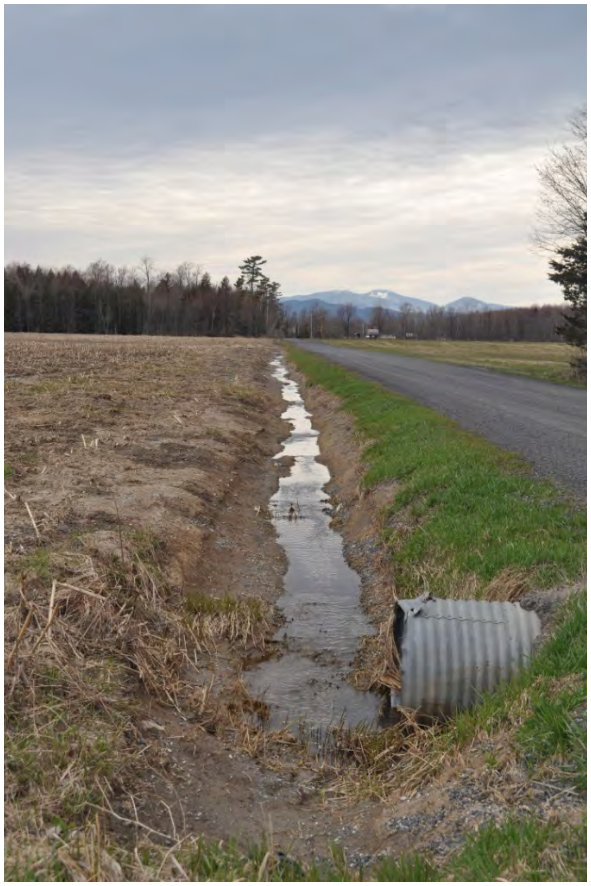


Figure 2.9. Cross Road site showing agricultural fields draining directly into sediment lade ditch without any buffer.

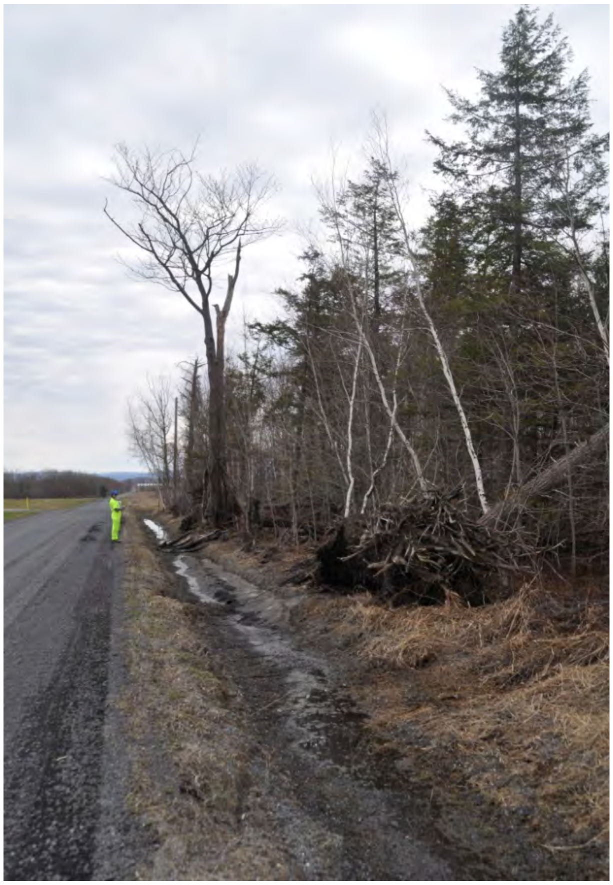


Figure 2.10. Cross Road site showing uprooted trees indicating that the water in the ditch is unable to drain causing issues with erosion..

Site 2 was a rock-remediated ditch located on Monkton Road between Middlebrook and Pea Ridge roads. This site was located next to a large agricultural farm, and rock remediation had obviously provided some benefit to the ditch network. However, upon closer examination, pipes carrying runoff water (most likely from tile drains in fields) ran directly into the ditch, causing the water to smell very strongly and covering it in a white shiny film (Fig. 2.11). Vegetation in this ditch was murky and rotting, and further along the ditch, rock remediation stopped. The water was draining directly into a stream only a hundred meters down the road. At this site, it would be important to not only test the water for contaminants, but also continue the rock-lined ditching all the way to the stream. Most importantly, the pipes draining effluent from the fields should not spill directly into the ditch network, but should instead be filtered through a vegetated buffer or holding pond before draining into the ditch network.

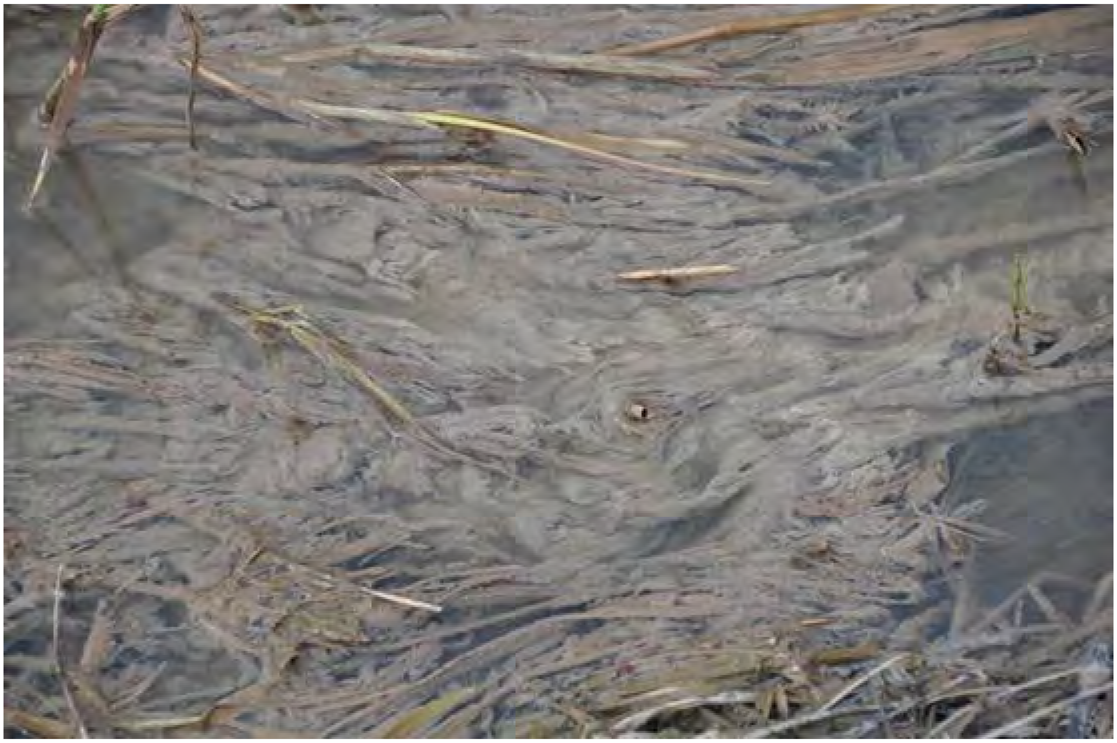

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Figure 2.11. Monkton Road site where runoff from pipes dumped field runoff directly into the roadside ditch. Ditch water is pictured above.

Site 3 was located on Parks-Hurlburt Road, and featured a highly eroded ditch next to agricultural lands. Although there was a 10 foot buffer between the field and ditch, this had no effect on filtering the drainage since several large field cuts had been made to drain water (Fig. 2.12). Because of this added water flow, the ditch was highly eroded and carried large amounts of sediment. At the top of the road, the ditch had a depth of 24 inches and a width of 72 inches (1 : 3 ratio). After a few field cuts over the next few meters, the ditch had changed to a depth of 60 inches and a width of 66 inches (approximately 1 : 1 ratio). Remediating this ditch site would require eliminating the field cuts and restoring the ditch by decreasing the depth created by the down-cutting water, as well as vegetating the ditch

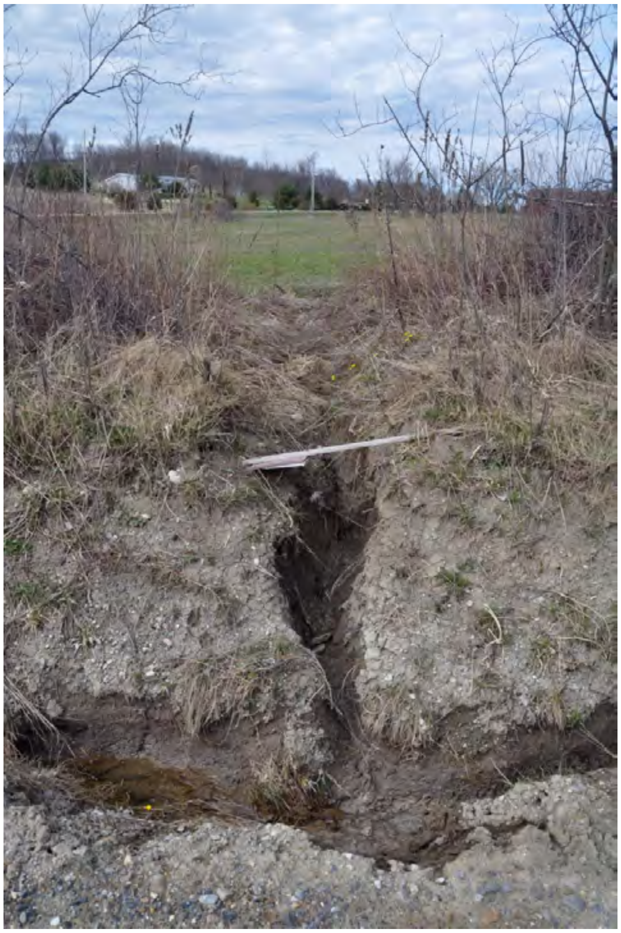

Figure 2.12. Parks-Hurlburt site showing a farmer's field cut directing agricultural runoff through the buffer and into the ditch.

Site 4 was located on a very steep road segment located next to a forest on the northern side of Quarry Road right before it intersects with Lime Kiln Road (Fig. 2.13). This site was selected because it showed a very steep road with a down-cut poorly maintained ditch, draining almost directly into a stream at the bottom of the hill. The ditch had a depth of 22 inches and width of 30 inches (2 : 3 ratio). Rock remediation would be the optimal choice for this site.

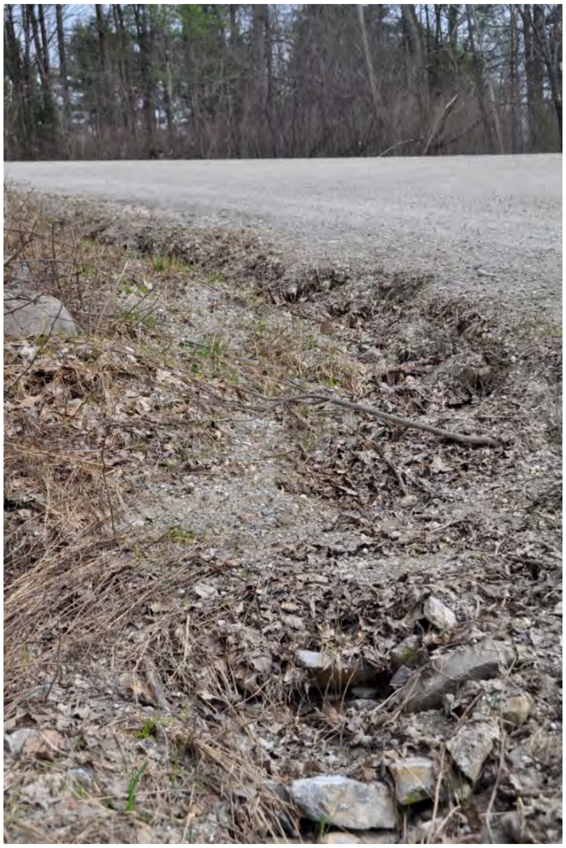

Figure 2.13. Quarry Road site. This steep ditch directed the fast moving sediment right into a stream at the bottom of the hill.

"Well Maintained" Site Studies

Site 5 was an example of a well-vegetated ditch located next to pasture and a home yard on Wing Road (Fig. 2.14). This was selected as a good site because the ditch was well-vegetated, carrying clear water, and had a good depth to width ratio (1 : 2).

Site 6 was an example of a rock-remediated ditch located at an important place—right before draining into a larger stream (Fig. 2.15). This ditch, located where Leduc and Pea Ridge Roads intersect on Plank Road, was able to capture suspended sediment and slow the water before entering the stream.

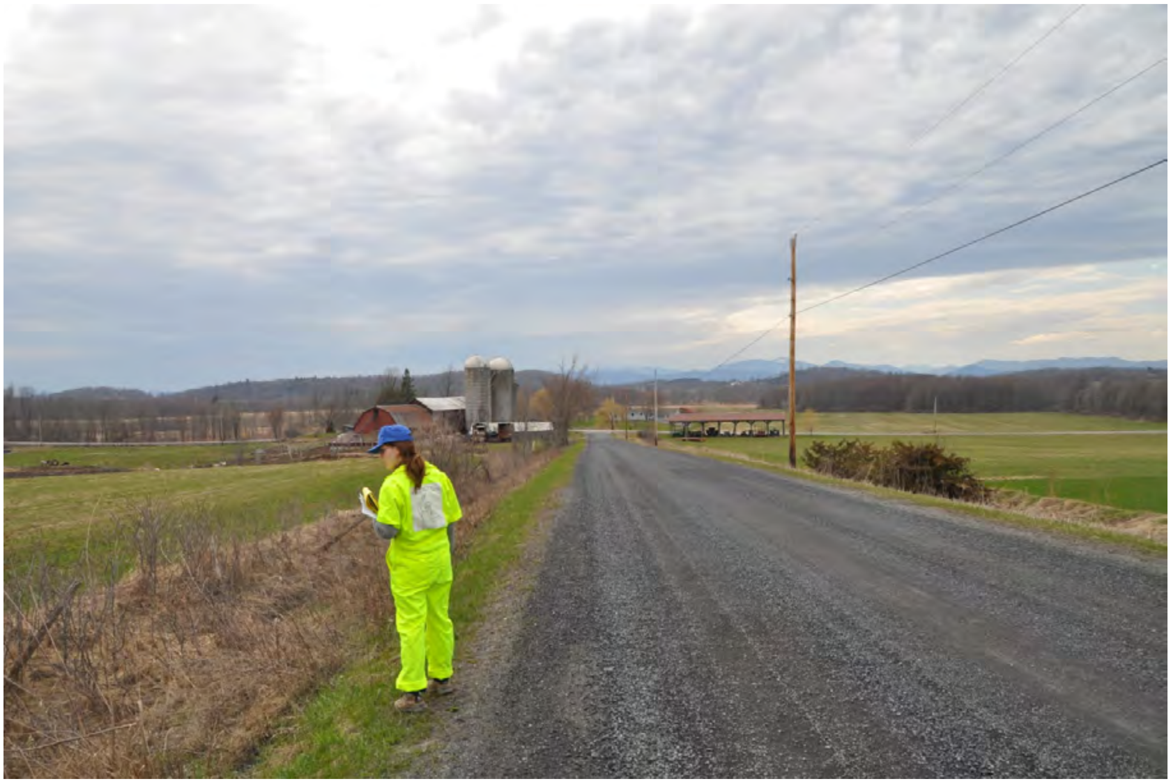

Figure 2.14 shows the Wing Road site with a vegetated ditch that traps phosphorus before the water drains into nearby streams.

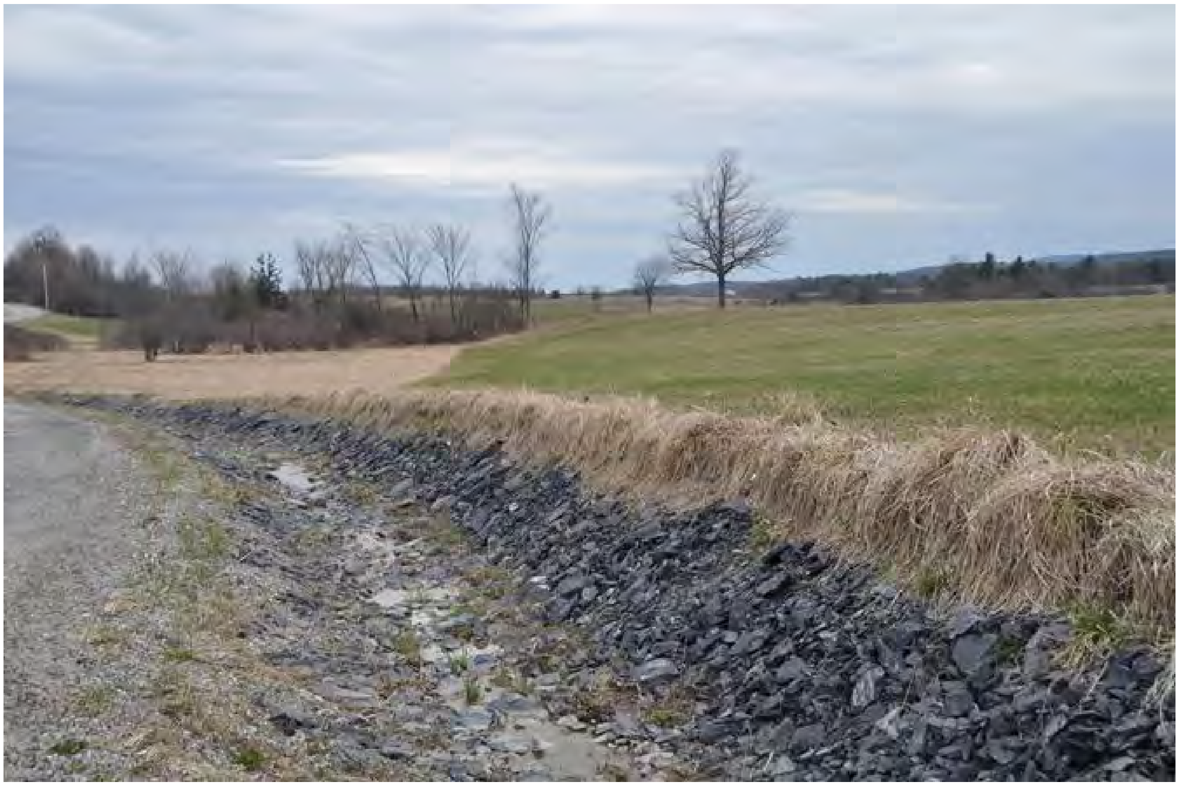

Figure 2.15 shows the Leduc and Pea Ridge Road site with a rock-lined ditch that slows water running down the slope and reduces erosion along the bank.

Discussion and Recommendations

The primary goal of this study was to identify the most effective ways in which towns could manage runoff that flows through roadside ditches, picking up and transporting phosphorus-laden sediment into rivers and eventually into Lake Champlain. Because Addison County is a blended residential and agricultural area, the maintenance of ditches becomes even more important. Water can flow very rapidly over large cultivated fields or livestock enclosures where there is no vegetation to buffer it. When water flows rapidly over residential impervious surfaces, it picks up large amounts of sediment and nutrients (Chapter 3 of this report, p. 3-12). Water from both sources frequently ends up traveling through and along roadside ditches and into the river network.

Our study has shown that the Little Otter Creek ditch network has a good base to work from, with about 60% of the ditches falling into the "well-maintained or remediated" category. We believe that this percentage can be easily improved with a dual remediation strategy. First, we recommend prioritizing the implementation of buffers by ditches that have been identified as "poorly-maintained." Most of all, these vegetated buffers should be placed by agricultural lands located on "highly erodible soils." This will slow and filter water, so in an area where water is flowing rapidly off a field surface carrying a great deal of sediment, an effective buffer of vegetation can dramatically improve the runoff situation.

Second, we recommend improving and restoring wetlands located close to the mouth of the rivers – essentially, within five miles of Lake Champlain. Wetlands are one of the most effective filtration systems for removing excess phosphorus and other water-borne pollutants from moving water. As a side benefit, they provide critical habitat for many species of birds and amphibians and can help reduce flooding during meltwater fluxes. Improving the wetlands would create a tremendous natural filter for runoff moving through ditches before it reaches Lake Champlain. Vegetated buffers and wetland remediation are filtration systems that are both highly effective and easy to maintain as, if constructed well, they are usually self-sustaining. We recommend investing in these straightforward ditch remediation strategies in order to improve the health of our local waterways in the Little Otter Creek watershed as well as the health of the greater Lake Champlain watershed.

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Miner, Craig. "Addison County River Watch Collaborative: Little Otter Creek - 2010 Water Quality Summary." (2010). Print. Accessed 12 March 2011. Available from http://www.scribd.com/doc/49654124/Little-Otter-Creek-2010-Water-Quality-Summary.

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Personal Resources/Interviews:
Beverley Wemple, Ph.D., Associate Professor, Department of Geology, UVM
Michael Ingram, undergrad student, UVM
Better Backroads: Jarrod Becker, Business Manager; Alan May, Better Backroads Technician
Vermont Agency of Transportation: Jonathon Croft, VTrans Mapping Unit; Kevin Vani, AOT Technician, Highway Safety and Design

Online resources for further investigation:
http://blueandwhitecrew.org/overseerinfo/erosion.php has good information on water bar construction and maintenance, although it is intended for hiking trails and not roads.

http://www.extension.umn.edu/distribution/naturalresources/DD6975.html is the source for "broad-based dip" information. Very well detailed and has a nice schematic diagram.

http://www.aces.edu/pubs/docs/A/ANR-0916/ANR-0916.pdf has good information on turn-outs and on broad-based dips as well as a few other water diversion structures.

http://dhn.iihr.uiowa.edu/runoff/erosion.htm is a really good source for definitions of splash, rill, sheet, gully and stream channel erosion.

http://www.ruralhometech.com/RoadDrivewayMaintenance/ADitchInTime/tabid/79/Default.aspx#6 - has some great information on road profiles, erosion, and how to build a good road.

Chapter 3. Analyzing and Documenting Floodplain Development in the Addison County Region

Jon Campbell
Kate Macfarlane
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Joe Baisch

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Introduction

The 2010 Lake Champlain Phosphorus Total Maximum Daily Load (TDML) Implementation Plan identifies development as a significant cause of phosphorus pollution (Vermont Clean and Clear). Unlike the natural surfaces that they replace, impervious surfaces (like roads and rooftops) do not absorb stormwater runoff, which often carries a heavy phosphorus load. As water rolls across impervious surfaces, it gathers speed and washes phosphorus and other pollutants into streams or storm drains (LCBP 2008). Furthermore, land conversion often results in erosion, which further increases phosphorus loading (Vermont Clean and Clear). Within the broader category of development, development that occurs in floodplains or adjacent to water bodies is of particular concern because of the reduced potential to implement runoff mitigation measures such as retention ponds or roadside ditch remediation (LCPB 2008; Chapter 2 of this report).

Floodplain development is also problematic because of the threat that it poses to human life and property. In August 2008, floods tore through the town of Ripton, washing away bridges and parts of Route 125, flooding basements, and stranding dozens of residents in their homes for days. In the aftermath of the disaster, evacuees were sent to an ad hoc emergency shelter in the Middlebury municipal gym, helicopters flew overhead assessing the damage, and Governor Jim

Douglas declared, “I think this is the most significant (natural disaster) in my tenure.” All told, damages from the flood exceeded $1 million (*Addison Independent*, 2008).

Flooding is a perennial problem in Vermont. Since 2000, FEMA has declared nine major flooding-related disasters in Vermont (FEMA 2011). Floodplain maps are used by policymakers, insurers, and developers to determine probability and to make development decisions. However, the FEMA maps currently used to determine flood zones and assess risk are far from perfect. In Vermont, only one-third of flood damages occur within FEMA-designated flood zones, compared to the national average of two-thirds (Medlock 2009). The topography of Vermont accounts for much of the difference; in Vermont, most floods occur as flash floods rather than as more gradual inundation events (Bouton, personal communication). According to a pamphlet produced by the Vermont Law School, “Vermont’s steep slopes and frequent flash flood events may render structures near upland streams more susceptible to flooding” (Medlock 2009, 6).

The Fluvial Erosion Hazards Program, adopted in 2003 by the River Management Program of the Vermont Agency of Natural Resources, has been working with localities to produce maps that more accurately assess the risk of flood hazard given the specific geomorphology of Vermont’s rivers. Over 75 percent of damages caused by the five major Vermont floods of the 1990s were due to erosion (VT ANR 2010). To date, fluvial erosion hazard (FEH) zones have been produced for the towns of Middlebury, Ripton, Lincoln, Bristol, New Haven, and Starksboro in the Addison County region, though those for Bristol and New Haven are still in draft form (Figure 3.1).

Our community partner, Tim Bouton at the Addison County Regional Planning Commission (ACRCP), identified the need for updated maps of floodplain development in the region. The last floodplain development maps were created in 2003, and do not reflect recent development or the new FEH zones. For this project, our principal objective was to provide ACRCP and towns in the Addison region with updated maps of development within flooding zones. Furthermore, we explored some of the additional economic and emotional costs of living within a floodplain.

A disaster is effective in galvanizing change in development and hazard mitigation practices for about eighteen months (Bouton, personal communication). After this critical time period, people begin to forget about the catastrophe’s gravity and care less about limiting the damages from such events in the future. Thirty months after the flood of August 2008, the Ripton bridges have been rebuilt, basements have been drained and dehumidified, and Route 125 sports a sleek new makeover. Has the town’s collective memory been rebuilt along with its roads? Have the stories of the flood victims been preserved and are they shaping the way development and hazard mitigation practices occur in the area? These questions permeated our project, and provided the motivation for updating floodplain development maps, for documenting local stories about flooding so as to preserve these memories, and for making all of this information accessible and easily understandable to all audiences.

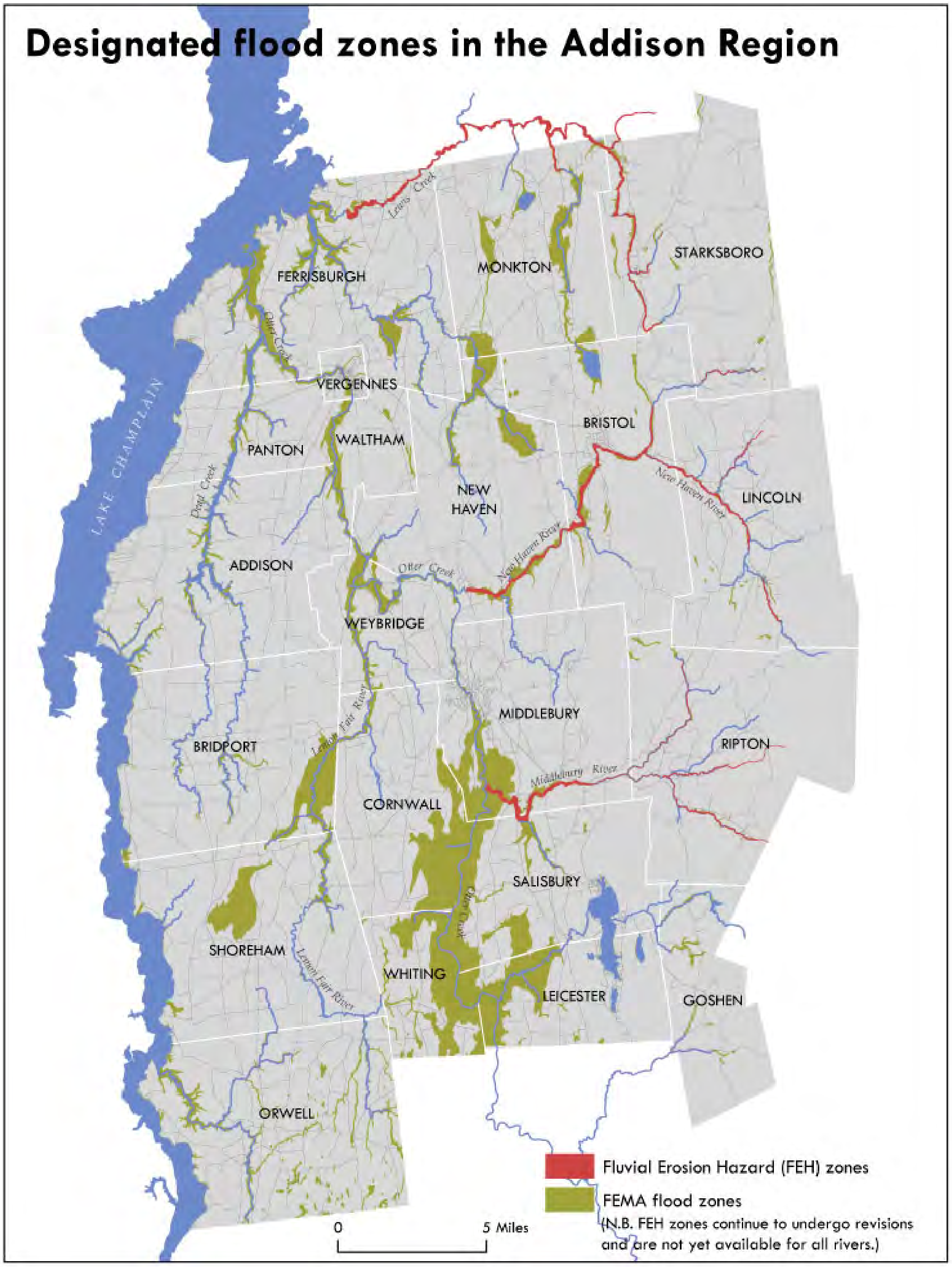


Figure 3.1. An overview of the extent of the different flood zones in the Addison County region.

In brief, the general objectives of our group were to:

1. Create new floodplain development maps for Addison County town plans, using FEH zones, FEMA flood zones and Vermont State E911 points.
2. Conduct a preliminary economic analysis of the costs of floodplain development, including estimates of assets at risk and floodplain premiums.
3. Use remote sensing and spatial analysis to assess the concentrations of impervious surfaces in a case study area of floodplain development.
4. Document past floods through audio interviews, video, and photographs in order to draw attention to the human costs of floodplain development.
5. Develop an interactive map to present the results of the previous four objectives to a non-technical audience.

Objective 1 - Updated Development Maps

To assess the amount of development within FEMA and FEH zones, we used GIS to map current Emergency 911 (E911) sites and examine where those points overlap with the flood zones. E911 points for 2011 and shapefiles of FEMA and FEH zones were provided by ACRPC. Figure 3.1 shows the extent of FEMA and FEH zones within the Addison County region. (The Addison County region refers to the part of Addison County that is included within the ACRPC and includes all Addison County towns except for Granville and Hancock). For each of the twenty-one towns in the Addison County region, we created a map showing E911 points within FEMA and FEH zones (where available). Figures 3.2-3.3 show examples of these maps. The full set of updated development maps can be accessed through the ACRPC.

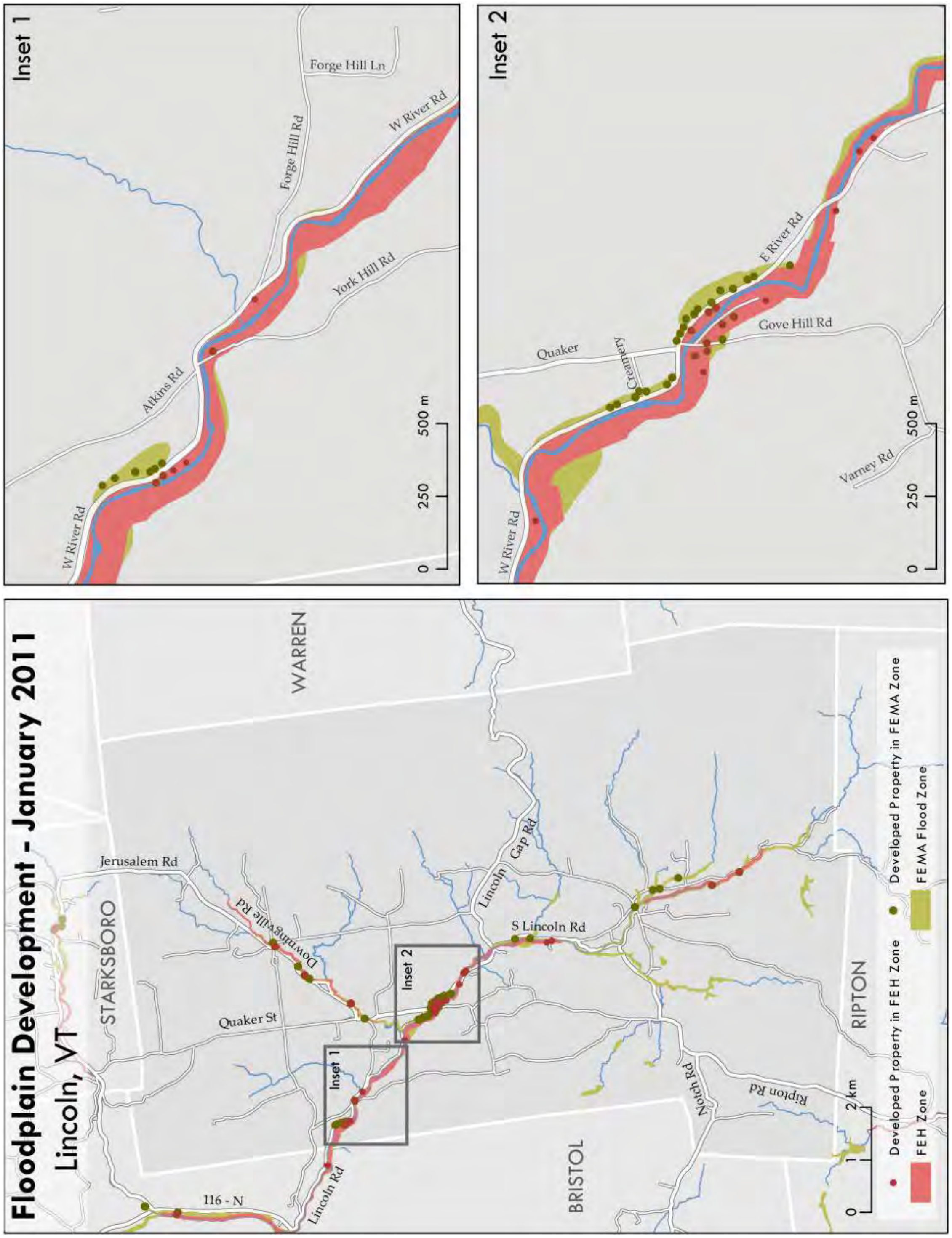


Figure 3.2. Updated floodplain development map for Lincoln.

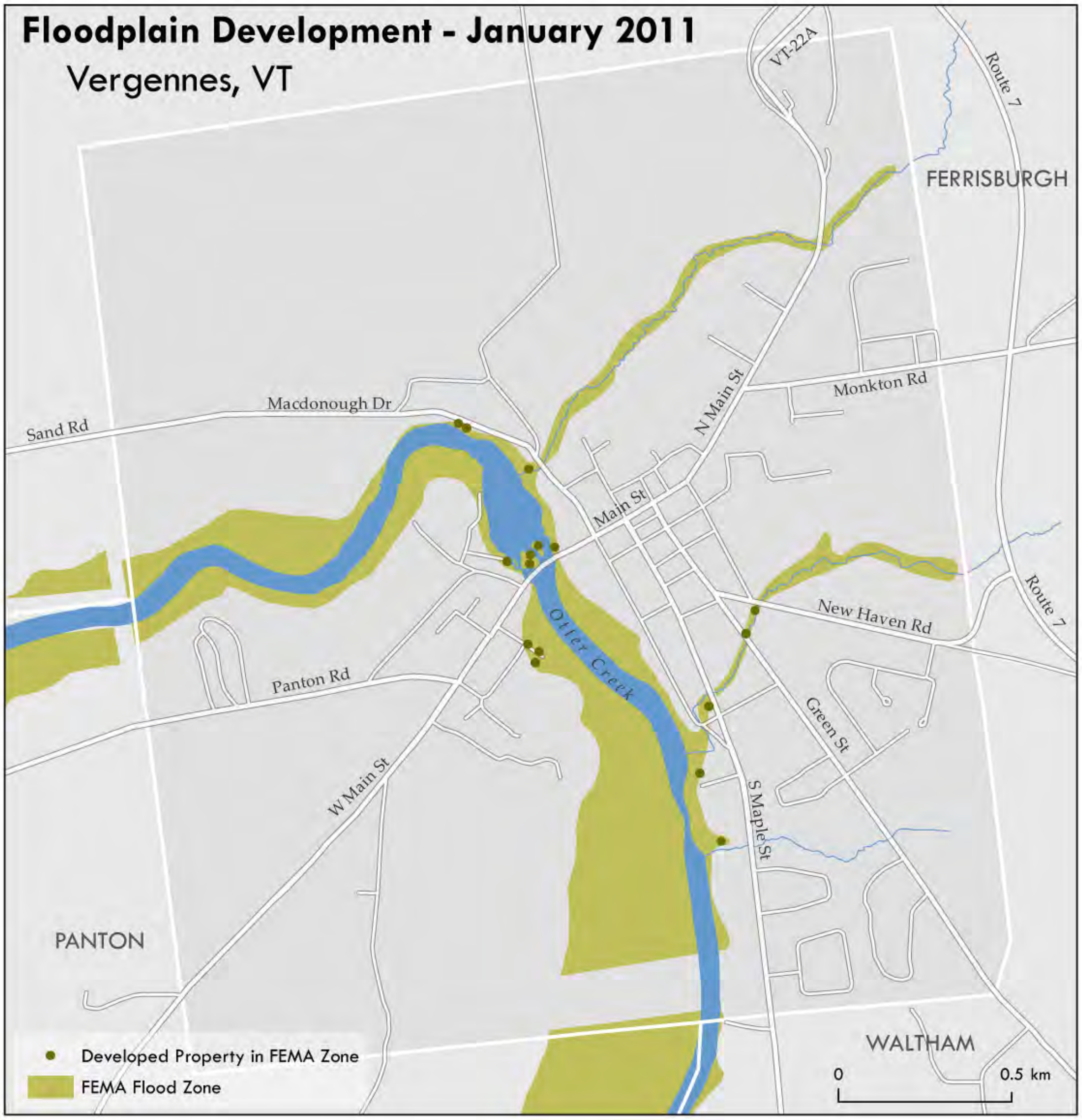


Figure 3.3. Updated floodplain development map for Vergennes.

In order to reveal more general patterns of floodplain development within the county, we mapped clusters of E911 points within FEMA zones (Figure 3.4). This map can be used by the ACRPC to help plan where to focus their efforts to prevent development within flood zones. These development clusters were created through a kernel density function, which gives values to raster cells based on the number of points within a certain distance (1 mile for our analysis). Because many of the E911 points within flood zones are closely clustered, they are difficult to distinguish on the county-scale maps. Depicting these clusters through the density function provides a more visible representation of development concentration than only mapping the E911 points.

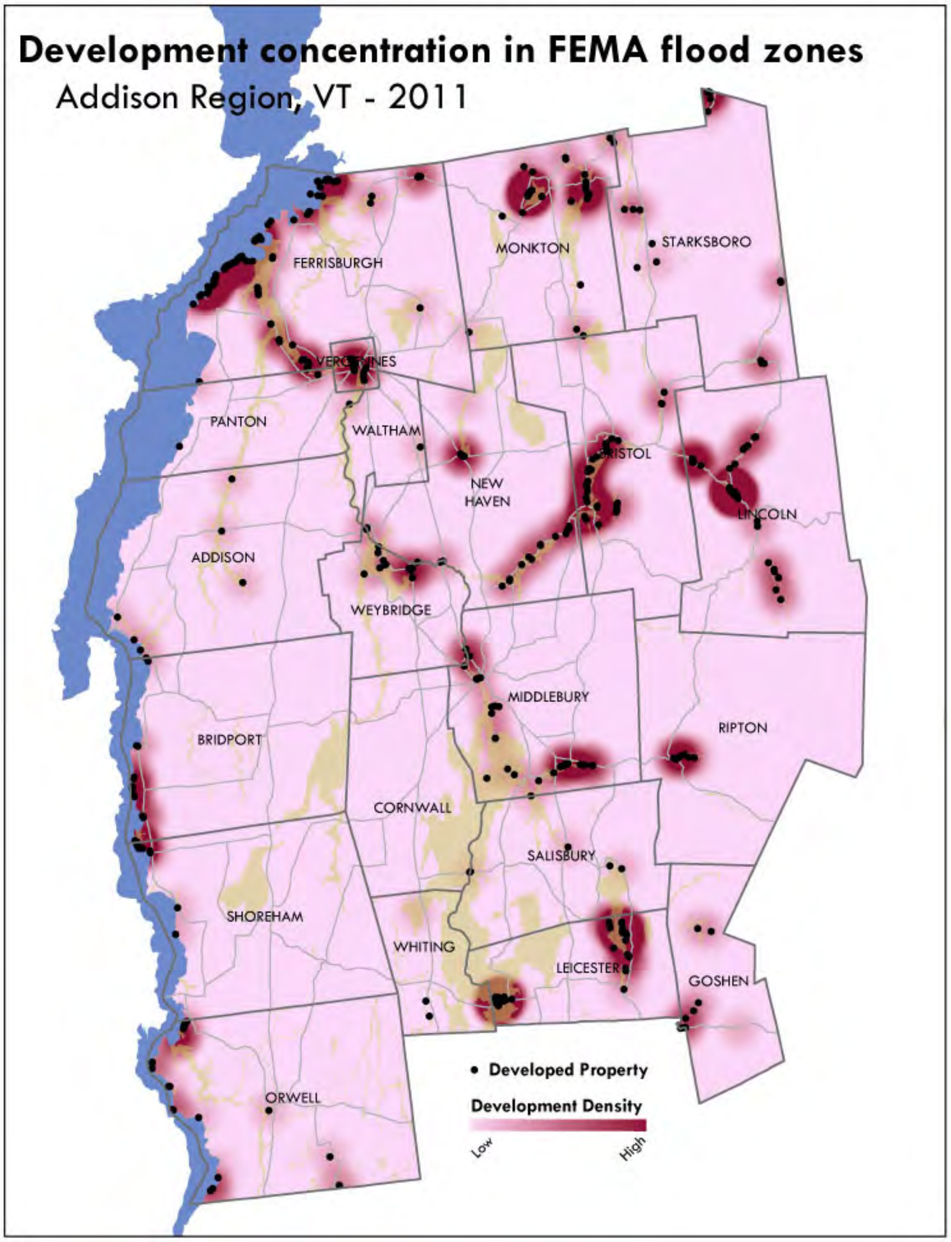


Figure 3.4. Concentrations of floodplain development in the Addison County region.

Acquisition of useable data proved to be our largest challenge for this portion of the project. Although we had initially hoped to examine floodplain development over time, data integrity issues made this task impractical. Specifically, E911 points representing the same addresses do not line up spatially from year to year, which severely hindered our ability to accurately analyze development trends. Further, some of the data provided to us by the ACRCP contained topological errors. For example, the FEMA floodplain data was created by digitizing paper maps, a process which left gaps between what should be adjacent sections. FEH shapefiles lacked metadata explaining who produced them, when they were produced, or how complete they were.

Objective 2 - Economic Analysis

Methodology

When development occurs in floodplains, not only does the price of insurance increase for home and business owners, but the assets themselves face greater potential damages. These risks can be avoided if floodplain development is prevented wherever possible. Consequently, the true cost of flood events must incorporate asset value losses as well as repair and redevelopment costs. After identifying the extent to which development has changed in our focus towns, we will attempt to determine the average asset value of homes in areas at risk. Risk areas will be fluvial erosion hazard zones, where available, and FEMA flood zones where no FEH zone is available. Once we determine each town's average asset value, we can develop a sense of the total potential cost of flood events. This will help convey the financial impact of flooding in Addison County, and aid town planners in grasping the economic vulnerability of certain areas to flood events. For our economic analysis, we focused on Middlebury, Ripton, Lincoln, Starksboro, New Haven, and Bristol as representative examples for the region.

Furthermore, it came to our attention that banks engage in the practice of demanding the purchase of flood insurance for homes within a 50-foot radius of a floodplain. This can make obtaining a mortgage all the more difficult for prospective homebuyers in Addison County. Thus, we incorporated relevant flood insurance prices mandated by these banks and determined the number of homes in the 50-foot buffered areas to quantify potential insurance costs.

One issue we encountered was accurately estimating the value of homes in the flood zones. While our community partner, Tim Bouton, suggested a range of $200,000 to $250,000, there may exist larger variability depending on distance from rivers. Publicly available asset values for the town of Middlebury exist online, but the remaining five towns lack this digital information. For the other five towns, we used median home sale prices for the year 2008. Note that flood sensitive areas tend to increase in danger the closer they are to the source of flooding, which incidentally tends to increase the value of a property deemed near an amenity. Thus, the accuracy of this methodology may not lend itself to detailed estimations of total asset values in Ripton, Lincoln, Starksboro, New Haven, and Bristol, but can provide a sense of the assets at risk.

Results

Table 3.1a displays the standard rated policies for sites in high-risk areas such as floodplains. The policy estimates provide a sampling of the different options available to site owners depending on whether they choose to cover both their building and its contents or building/contents only. Tim Bouton of the Addison County Regional Planning Commission provided these data.

Table 3.1a. Standard rated policies for high-risk residential areas, USD. Three types of coverage, building and contents, building only, and contents only, are displayed below.

Standard Rated Policies: High-Risk Areas

Building and Contents		**Building Only**		**Contents Only**	
Coverage	**Annual Premium**	**Coverage**	**Annual Premium**	**Coverage**	**Annual Premium**
$35,000/$10,000	$472	$35,000	$376	$10,000	$136
$50,000/$15,000	$634	$50,000	$490	$15,000	$184
$75,000/$20,000	$848	$75,000	$656	$20,000	$232
$100,000/$30,000	$1,100	$100,000	$806	$30,000	$334
$125,000/$40,000	$1,357	$125,000	$956	$40,000	$441
$150,000/$50,000	$1,614	$150,000	$1,106	$50,000	$548
$250,000/$100,000	$2,734	$250,000	$1,691	$100,000	$1,083

Table 3.1b lists the number of sites, determined from 2011 E911 points, within each town's floodplain (determined from each town FEMA zone) and within a 50-meter buffer zone beyond. Banks utilize FEMA boundaries in their flood insurance analyses, so those zones are used in place of FEH zones. There exists a significant difference in the number of sites directly within the floodplain compared to those within the 50-meter buffer zone, which suggests that the costs of floodplain development extend beyond FEMA boundaries.

Table 3.1b. Number of sites in six focus towns that exist within FEMA floodplains and within a 50-meter buffer zone beyond the floodplain.

High-Risk Sites in Floodplain Development

Town	**# of sites within floodplain**	**# of sites in 50m buffer zone**
Middlebury	18	198
Ripton	9	32
Lincoln	16	123
Starksboro	21	92
New Haven	24	67
Bristol	35	134

Table 3.2 estimates the total and average asset values of homes in Middlebury within FEH zones. Each address represents the most recent E911 point (Listers). The total real value of at-risk assets in Middlebury is the sum of the 18 E911 sites within FEH zones.

Table 3.2. Middlebury's residences located within the FEH zone, their values in 2010 USD, and the total at-risk asset value in the FEH zone.

Assets in FEH zones, Middlebury, VT

Address	Designation	Real Property Value
4 LOWER PLAINS RD	Single Family	203,700
478 EAST MAIN ST	Single Family	170,900
474 EAST MAIN ST	Single Family	155,300
468 EAST MAIN ST	Single Family	149,100
472 EAST MAIN ST	Single Family	153,300
466 EAST MAIN ST	Single Family	232,300
5 GRIST MILL RD	Single Family	207,700
1 LOWER PLAINS RD	Single Family	253,300
464 EAST MAIN ST	Single Family	175,500
2 LOWER PLAINS RD	Single Family	230,600
2 GRIST MILL RD	Single Family	187,400
1 GRIST MILL RD	Other	121,300
438 EAST MAIN ST	Single Family	148,200
428 EAST MAIN ST	Multi Family	205,500
430 EAST MAIN ST	Single Family	196,000
426 EAST MAIN ST	Single Family	172,600
422 EAST MAIN ST	Single Family	108,600
420 EAST MAIN ST	Single Family	151,800
	Avg Real Value in FEH	**$179,061**
	Total Real Value	**$3,223,100**

Table 3.3 attempts to estimate the total and average asset values of homes in Ripton, Lincoln, Starksboro, New Haven, and Bristol. Due to our difficulty determining the asset values of all E911 points in these towns, as we were able to do in Middlebury, we used the median values of homes sold in these towns in 2008. These are split into two categories: homes on > 6 acres and homes on < 6 acres. These estimates provide a range of possible average asset values in the five towns. Total asset values are calculated by multiplying the average asset value range by the number of homes in each town located in FEMA zones.

Assets in FEMA zones

Median values, Based on 2008 home sale prices

(3)* Indicates # of homes sold in 2008

Ripton	<6 acres (3)*		>6 acres (2)		**Homes in FEMA zone, 2011**	**Possible Asset Value Ranges**
		$165,000		$277,500	9	**$1,485,000 -$2,497,500**
Lincoln	<6 acres (6)		>6 acres (3)			
		$186,000		$175,000	16	**$2,800,000 -$2,976,000**
Starksboro	<6 acres (10)		>6 acres (2)			
		$178,150		$312,500	21	**$3,741,150 -$6,563,500**
New Haven	<6 acres (1)		>6 acres (4)			
		$211,500		$302,500	24	**$5,076,000 -$7,260,000**
Bristol	<6 acres (15)		>6 acres (5)			
		$196,500		$180,000	35	**$6,300,000 -$6,877,500**

Table 3.3. Asset values of selected towns in Addison County based on median values of 2008 home sale prices (USD). The number of homes in FEMA zones is based on 2011 E911 data and the most current FEMA zoning criteria. Median values based on fewer home sale prices will reflect a less accurate valuation of real asset values.

Objective 3 - Impervious Surfaces

One of the primary ways in which floodplain development increases phosphorus loading into the rivers of the Lake Champlain basin is through the expansion of impervious surfaces. Impervious surfaces facilitate runoff during precipitation and snowmelt, increasing the flow of phosphorus into rivers. In addition, an increase in impervious surfaces causes decreased infiltration of water and phosphorus into the soil before it reaches a body of surface water. Stream ecosystems become impaired when as little as 10 percent of the catchment is developed as impervious surface (Withers and Jarvie 2008). Thus, to accurately measure the effect of development on a municipality's contribution to phosphorus loading, the area of impervious surfaces in floodplain regions must be quantified. Unfortunately, impervious surface analysis has traditionally been a costly endeavor, requiring expensive remotely sensed imagery and extensive labor hours.

Our goal was to develop a cost and time effective methodology for municipalities to *estimate* impervious surface area within their floodplain regions. We chose two Addison County towns to serve as study sites for the impervious surface analysis due to their high concentrations of development in flood zones – Lincoln and Ripton. While these are both mountain towns with high floodplain development, Lincoln has more cleared land, while much of Ripton's developed property is still on wooded lots. By using these two towns for the case study, we can qualitatively assess the degree to which the "leaf-on" nature of NAIP imagery affects impervious surface assessment.

Methodology and results

As the remotely sensed imagery files needed to do impervious surface analysis typically comprise the majority of a project's cost, we rely on freely available NAIP (National Agricultural Imagery Program) images, obtained from the Vermont Center for Geographic Information (VCGI). As a tradeoff, however, the NAIP imagery has a limited spectral bandwidth and resolution. In addition, as the images were intended for agricultural use, they were taken with leaves on the trees, obscuring some impervious surfaces under tree canopies. Image preprocessing and analysis was conducted using ERDAS IMAGINE 10 and ArcGIS 10.

Imagery was downloaded from VCGI as USGS quarter-quad tiles. To form complete images of each of the study areas, we stitched the images together, using dodging and histogram matching to correct for color imbalances across the images. These preprocessed images were used as the base for a supervised classification analysis. Land cover was classified into four categories: impervious surfaces, surface water, forested land, and non-forested rural land following the example of Yuan and Bauer (2006). In order to run the analysis, training data "areas of interest" were defined to give the algorithm examples of each land cover type. For each land cover class, thirty areas of interest (at least

100 pixels) were designated on the imagery. Care was taken to ensure both non-shadowed and shadowed examples of each class were defined to avoid misclassification. With the areas of interest defined, the map classification algorithms were run, yielding the rough classification maps, as seen in Figure 3.5.

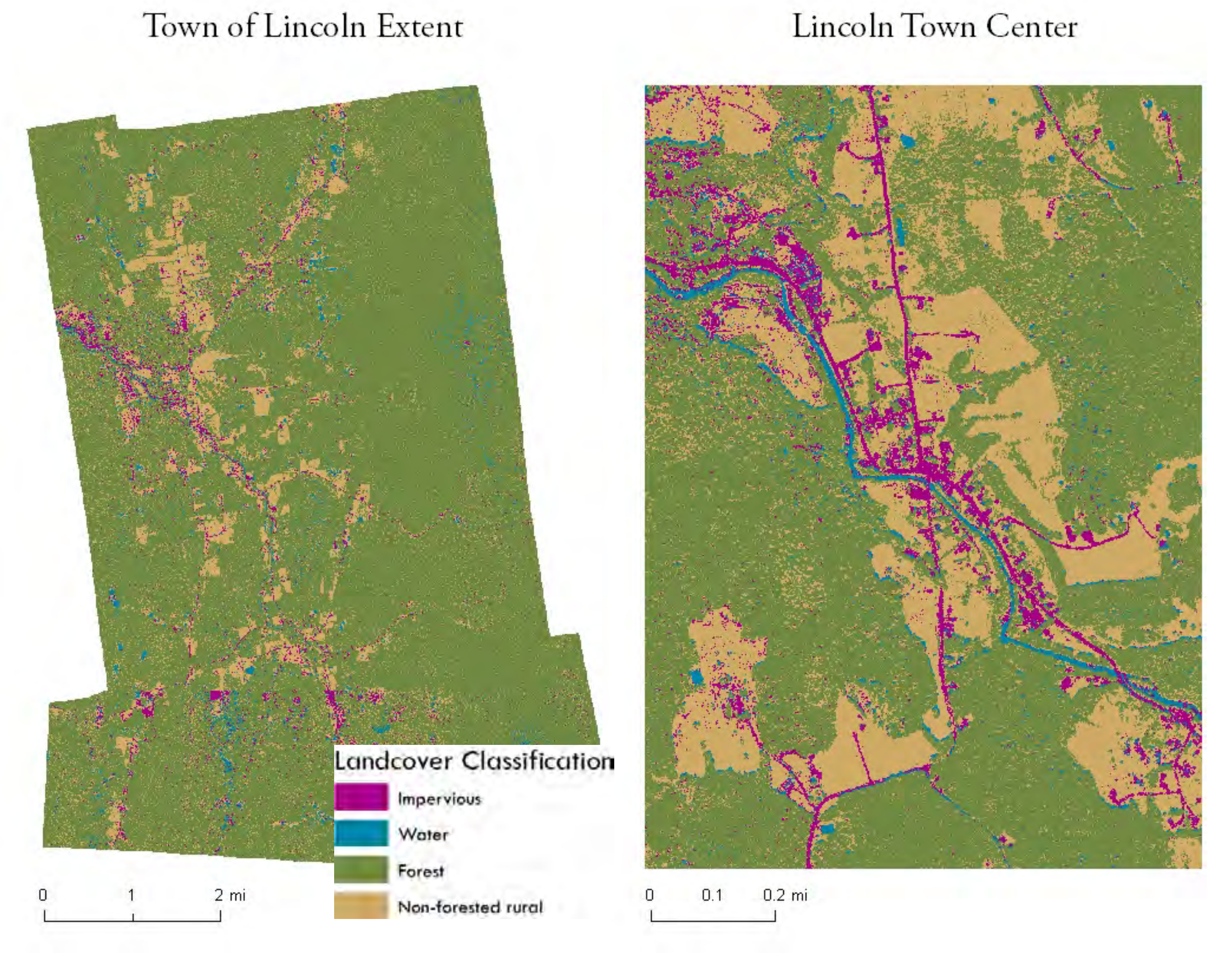
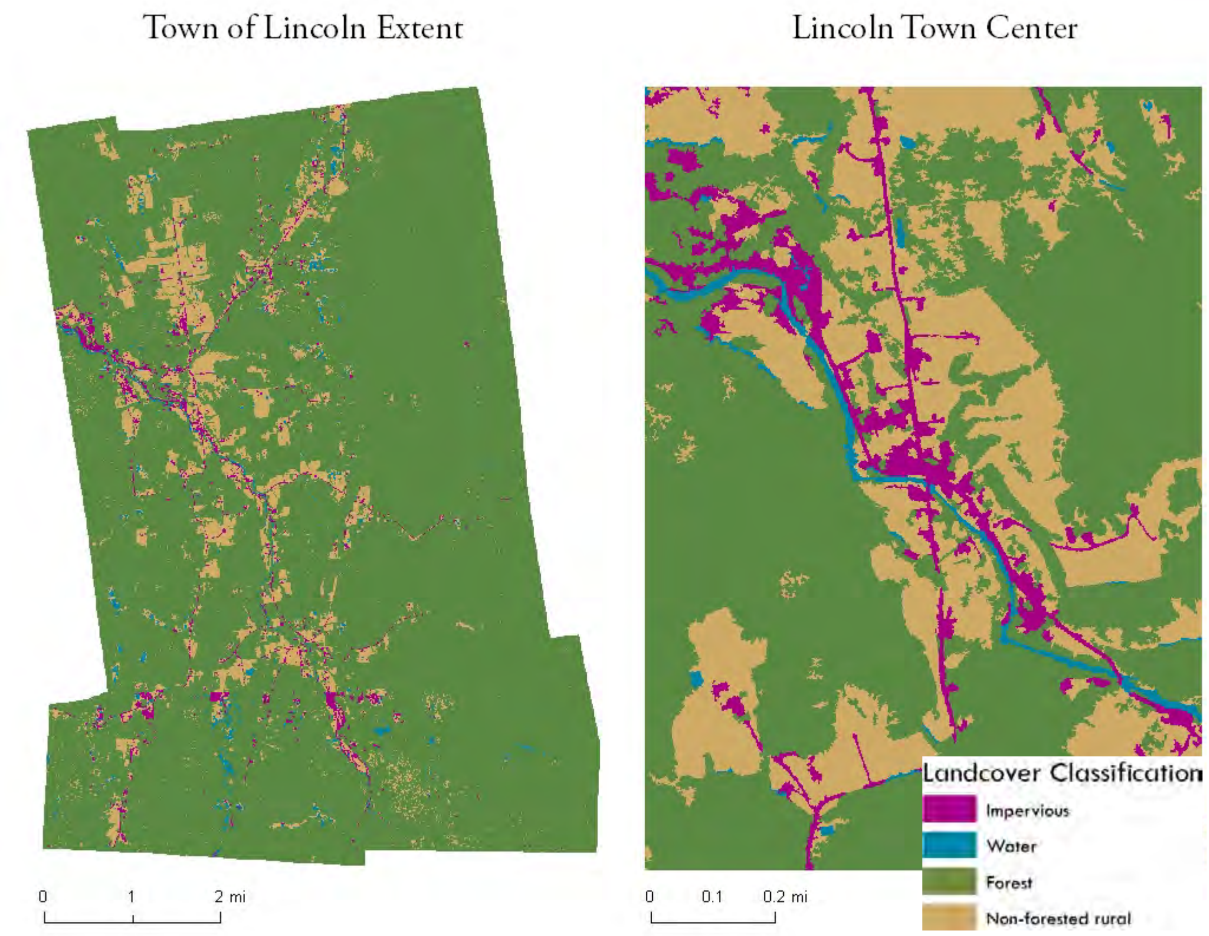


Figure 3.5. Initial impervious surface classification.

In order to fix misclassified cells and reduce background noise, we developed a post-processing algorithm in ArcGIS to clean up the classified image. The post processing procedure can be broken down into three subtasks—filtering to remove isolated pixels and background noise, smoothing class boundaries and clumping classes, and removing small, isolated regions. Typically, additional manual post-processing is done to further increase classification accuracy, but the time constraints of the project did not allow for this. The post-processed images for Lincoln are depicted below in Figure 3.6.


Town of Lincoln Extent

Lincoln Town Center

Figure 3.6. Post processed land classification maps of Lincoln.

In order to estimate the percentage of FEMA floodzones developed into impervious surfaces, we first clipped the classified land cover map using the FEMA floodzone as a mask as shown in Figure 3.7. This process was repeated for the FEH zones.

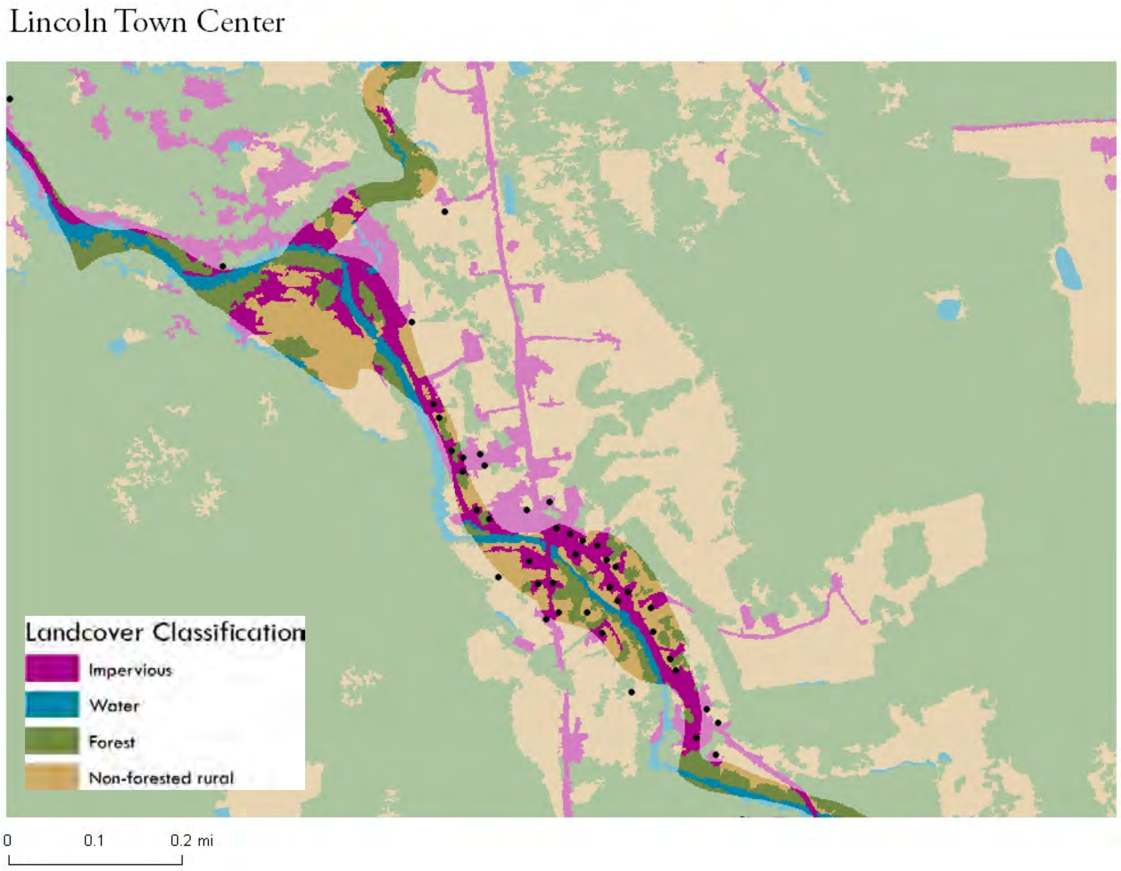


Figure 3.7. Impervious surfaces in Lincoln FEMA zones.

From these clipped images, the areas of estimated impervious and non-impervious surfaces within the FEMA and FEH zones were calculated. For the town of Lincoln, impervious surfaces make up approximately 14 percent of FEMA zones and 15.5 percent of FEH zones. In contrast, impervious surfaces only make up approximately 3 percent of FEMA zones and 3.6 percent of FEH zones in Ripton. This major difference is potentially due to much of Lincoln's town center being located in the floodzone, while Ripton's floodzone impervious surfaces are primarily roads and isolated houses. Additional work on this analysis would help to further process the classified images and in doing so, increase the accuracy of the classification. In addition, using this procedure for an area in which an alternate impervious surface analysis has been completed would assess the accuracy of this relatively quick procedure as a cost effective means for municipalities to measure impervious surface concentration.

Objective 4 - Interviews

To document the consequences of flooding on the lives of Vermonters, we interviewed nine residents in three flood-impacted towns: Ripton, Lincoln, and Bristol. In Lincoln, we spoke with David and Mary Harrison, residents of Lincoln since 1981 and1968, respectively. They are currently retired. At the time of the 1998 flood, both David and Mary held positions with the town's fire department. They managed much of the rescue and recovery effort in the days and weeks after the disaster.

In Ripton, we conducted interviews with Richard Ruane and Andrea Chessman, who have lived in the village since 1994. Richard is the education technologist at the Lincoln Community School, Andrea is an author and editor, and both are founding members of the Ripton Community Coffeehouse. During the flood of 2008, their home was surrounded by water and their yard and garden were washed away.

We spoke with Wendy Leeds and Tom McElhaney who have lived in Ripton since 1993 and the late 1990s, respectively. Wendy is a high school girls soccer and ice hockey coach and an administrative assistant at the Ripton Elementary School. Tom works at the Middlebury Natural Foods Co-op. They were stranded on Old Town Road after the August 2008 flood washed out part of Potash Bridge.

We also interviewed Hilda Billings, a lifelong resident of Ripton born in 1920, and her son Charles Billings. Hilda was the town's postmaster for 27 years and is currently an amateur botanist and historian. Charles is a Ripton native and a member of the Ripton Historical Society and the Ripton Planning and Zoning Committee. Hilda and Charles were both stranded in their Old Town Road home when the flood of August 2008 damaged Potash Bridge.

Finally, we interviewed Mark Bouvier, a lifelong resident of Bristol. He is currently the business manager at the Hannaford Career Center. During the flood of 1998, he was the fire chief of the town's fire department. Mark oversaw much of the rescue and recovery efforts after the disaster.

All of these individuals provided captivating stories and descriptions about their experiences with flooding. We were interested in hearing how the river and flooding were parts of life before the disasters in question; how their perceptions of the river and flooding changed after the disasters; how the floods directly affected their lives; what their opinions were on how development ought to be managed in FEH and FEMA zones; how the disasters affected their communities; and how they feel about their towns with concern to future flooding.

All of the interviews were transcribed and edited into 3-4 minute sound clips. The audio clips, along with brief biographies of each interviewee, can be accessed through the ACRPC, Diane Munroe (dmunroe@middlebury.edu) and through our interactive map once completed. The full transcripts of these interviews can be found in the Special Collection Archive—The Vermont Collection in the Middlebury College Library, the Vermont Folklife Center, and from Diane Munroe.

Objective 5: Interactive Map

Using Adobe Flash Catalyst, we began developing an interactive map to showcase and integrate the results of our other objectives. The goal is for the map is to include tools to zoom in on particular towns, play videos, and listen to stories from Vermont residents. We aim to finalize work on this map over the summer and will work with the ACRPC to advertise the web site link once available.

Conclusion

Through maps, economic analyses, and personal stories, we sought to tell the story of floodplain development in the Addison County region. Not only does floodplain development provide a significant source of phosphorus pollution, but it also places human life and property at risk. In Middlebury alone, $3,233,100 worth of assets exists within fluvial erosion hazard zones, areas most prone to damage during flood events. This estimate does not include public infrastructure such as bridges and culverts; it merely reflects real private asset value. Moreover, insurance providers often mandate their clients purchase flood insurance if their properties lie within a 50-meter buffer from FEMA zones. With an average real asset value of $179,061, residences in Middlebury face annual premiums ranging from $1,106 to $2,734 for flood insurance. In the future, development should be restricted to areas outside both FEMA and FEH zones, for the risks inherent in floodplain development impose costs on residents whether or not flood events occur.

By creating an updated collection of town floodplain development maps, we have provided town planners, watershed managers, and the ACRPC with a powerful visual tool for future planning and advocacy work. We hope that our results will be used to inform county residents about the extent of floodplain development within their area and to galvanize future action to discourage construction in flood-prone areas. With publicly accessible video and audio clips that express the personal, environmental, and economic impacts of floodplain development, we hope that this issue remains salient beyond the typical 18-month period after a flood event.

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Chapter 4. Improving Water Quality Language in Town Plans

Eamon Fogarty
Eleanor Horowitz
Brittany Lehnhart
Bente Madson

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The Problem of Phosphorus in Lake Champlain

The effort to preserve the water quality of Lake Champlain has run into significant problems over the years. Research has determined that the primary cause of the harmful algal blooms plaguing the lake is an excess of phosphorus entering from 'non-point' sources within its watershed. These sources are diffuse and various, ranging from roadside erosion, to excess stormwater runoff, to agricultural pollution. In 2003 Vermont created the Clean and Clear Action Plan to address the issue, but since then many people have become frustrated by the discrepancy between the amount of money spent and the lack of immediate visible results. A 2010 estimate showed roughly 100 million dollars had been spent on public programs to improve water quality in Lake Champlain. Due to these shortcomings, the EPA has recently taken over revision of the Total Maximum Daily Load of phosphorus for Lake Champlain. This process will take time, but in the mean time there are numerous opportunities to affect change on a local level through the power of Town Plans.

The Importance of a Town Plan

In the state of Vermont, Town Plans provide vision and direction for the growth and development of cities and towns. Local governments have planning boards composed of residents who volunteer their time to shape the future of their towns. In Addison County, these boards, with help from the Addison County Regional Planning Commission, draft the Town Plans and submit them for approval every few years. The Plans are legally binding documents and as a result, the goals and policies set forth in them must be carried out to the extent that resources allow.

Many towns in Addison County have concerns about water quality. Sedimentation, spread of pathogens, and nutrient enrichment are only a few of the problems that planners must address in their efforts to preserve the vital natural, economic, and aesthetic resources of their communities.

Fortunately, there is great potential to address these issues at a local level. Many of the programs and regulations are in need of revision to ensure the continued health of Vermont's rivers and lakes. In many cases the necessary change is as simple as replacing weak words with strong ones. There is a world of difference, in terms of policy implementation, between the word 'discourage' and the word 'prohibit.'

Town Plans lay the foundation for zoning bylaws, which are where many specific regulations and tangible implementation requirements can be found. The power of the Town Plan is that strong and effective Town Plan language can make effective zoning bylaws possible. Zoning bylaws are not written unless they have some precedent in or connection to the Town Plan. Strong plan language can also result in the creation of new programs, and the adoption of new or improved regulations where necessary. Zoning bylaws are the implementation of the ideals and direction provided by Town Plans. If Plans are firm and explicit in their policy language, appropriate zoning bylaws will follow. Town Plans can also call for additional support from and involvement in existing programs, as well as collaboration with non-profit organizations and citizen groups.

Our report highlights good policy language in current Town Plans and makes recommendations concerning elements that are either missing or in need of revision. In our report, you will first find a Model Town Plan with strong policy language to protect water quality, and then you will find town-by-town documentation of and recommendations for water quality policy in Addison County's current Town Plans. Our analysis pays particularly close attention to language related to the establishment and maintenance of riparian buffer strips and a call for the incorporation of Act 110, legislation that makes financial and technical assistance available for the establishment of riparian buffer zones, where it is relevant.

Excerpts from our Report

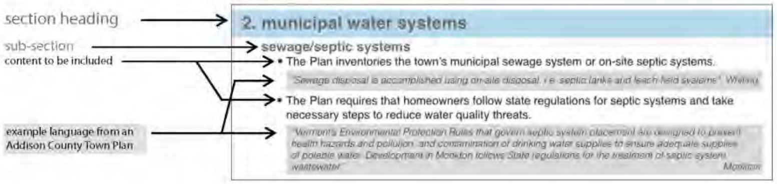
Since our final report is over ninety pages long, we will just share excerpts from the report in this compendium. The full report can be accessed from the Addison County Regional Planning Commission, from Diane Munroe (dmunroe@middlebury.edu) and at: http://www.middlebury.edu/academics/es/work/communityconnectedlearning/envs0401/archive. On the following pages you can view our Model Town Plan and our compiled results, trends, and rankings. We hope these excerpts also give you a sense of our layout and design—these were very important to us as we wanted to make a document that was visually appealing, user-friendly, and was able to make detailed information readily accessible.

how to use this document

This document is meant to serve primarily as a resource for Town Planners and other stakeholders for writing a plan that is sensitive to water quality issues.

model water quality language

The model plan divides the broad issue of water quality into five manageable categories. The categories are not meant to correspond with each towns' distinctive plan, but instead provide a comprehensible framework for understanding the content. Sub-sections include the recommended issue to be addressed as well as examples of existing good language from Addison County Town Plans.



2. municipal water systems

sewage/septic systems

- The Plan inventories the town's municipal sewage system or on-site septic systems.

"Sewage disposal is accomplished using on-site disposal, i.e. septic tanks and leach field systems." Whiting

- The Plan requires that homeowners follow state regulations for septic systems and take necessary steps to reduce water quality threats.

"Vermont's Environmental Protection Rules that govern septic system placement are designed to prevent health hazards and pollution, and contamination of drinking water supplies to ensure adequate supplies of potable water. Development in Monkton follows State regulations for the treatment of septic system wastewater." Monkton

evaluating Town Plans

In the second part of this document, the Town Plans from each of the twenty-one towns in Addison County are analyzed for the inclusion of strong water quality language. The document follows the same organization as the model plan and grades the language found in each town along the way. The document also includes individualized recommendations for how to improve and add to the existing language.

The ranking system, while subjective, is meant to help highlight areas of Town Plans that we feel need the most work. "Weak" symbols may highlight omissions or undesirable language while "strong" symbols may highlight good language that still has room for improvement.

model water quality language

1. natural resources

surface water

- The Plan identifies all surface water in the area.
- The Plan acknowledges water quality as an issue, specifically highlighting the effects of phosphorus.

"Surface waters are valuable as a water source, recreation areas, habitat for wildlife and vegetation, and an aesthetic resource. These values can be diminished by pollution, alteration, or overuse. This resource is complex and has been adversely affected by runoff, invasive species, and other biological factors. Shoreham

- The Plan indicates the quality of all surface water in the area, ideally in cooperation with the Addison County River Watch Collaborative.

"Cooperate with the Otter Creek River Watch in monitoring the river's water quality." Weybridge

- The Plan includes tangible ways to improve water quality.

"Monitor actions of towns and state and federal agencies that directly affect Weybridge's surface water quality and intervene as appropriate, prohibit or control the removal of gravel from streambeds and banks." Weybridge

groundwater

- The Plan indicates the quality and current state of town groundwater.

"Cornwall has sparse groundwater potential and every effort needs to be made to maintain its quality and quantity and protect recharge areas and aquifers. Most of the areas with good groundwater potential are near the Cornwall Swamp and the Lemon Fair. The quality of groundwater varies with some areas of town reporting varying concentrations of sodium and sulfur in the groundwater, while others report good quality. There are no Source Protection Areas in Cornwall, since there are no public water supplies." Cornwall

- The Plan includes tangible ways to improve groundwater quality.

"Pay special attention to aquifers and groundwater protection and explore the development of regulations that would create a groundwater protection overlay district to provide additional review of land uses within designated Source Protection Areas and restrict development that could contaminate public water supplies." Orwell

wetlands

- The Plan inventories all wetland areas in the Town.

See 'Vermont Significant Wetlands Inventory'

- The Plan indicates the importance of wetlands to watershed ecosystems.

Cornwall's wetlands, ranging from the large, nationally significant Cornwall Swamp to the smallest Class III wetland, are recognized as performing numerous ecological functions of importance to the broader ecosystem of the town and the entire Champlain Valley. Some, if not all, of these functions are very important to human communities and human welfare." Cornwall

- The Plan includes a wetland protection plan.
- The Plan references 'Vermont State Wetlands Rules'.

fish, wildlife & ecosystems

- The Plan discusses the connection between the Town, water quality, and ecosystem health.
- The Plan provides a tangible protection plan.

recreation

- The Plan references water-related recreation in the Town.
- The Plan includes a water quality protection plan to combat degradation due to recreation and high use.

2. municipal water systems

sewage/septic systems

- The Plan inventories the town's municipal sewage system or on-site septic systems.

> "Sewage disposal is accomplished using on-site disposal, i.e. septic tanks and leach-field systems" Whiting

- The Plan requires that homeowners follow state regulations for septic systems and take necessary steps to reduce water quality threats.

> "Vermont's Environmental Protection Rules that govern septic system placement are designed to prevent health hazards and pollution, and contamination of drinking water supplies to ensure adequate supplies of potable water. Development in Monkton follows State regulations for the treatment of septic system wastewater."
>
> Monkton

development limitations

- The Plan identifies development limitations for sewage and septic systems.

drinking water

- The Plan explains the source of drinking water.
- The Plan makes a connection between water quality and drinking water quality.

> The Plan "highly recommends that residence test their drinking water following the guidelines set by the VDH" in order to test for pollutants and contaminants. "Common sources of contamination from human activities include storage tanks, municipal landfills, illegal dumps and dumping, septic tanks, road salting and runoff, and some agricultural activities." Monkton

- The Plan addresses the capacity of the drinking water supply, the treatment process, and the threats of degraded water quality on drinking water supply.
- If served by the Tri-Town Water District or Lake Champlain, the Plan should connect the effect of Lake Champlain's water quality to the quality of the drinking water supply.

3. built environment

runoff

- The Plan explains how the built environment and/or impervious surfaces are a leading cause of surface water pollution, especially since its control lies much more within the town's regulatory power.

> "Sewage treatment plants, parking lots, highways, fields and forests drain into Otter Creek along its course. To protect surface water quality, inter-municipal coordination, planning and action are needed since activities affecting water quality at any point in the system affect water quality of all downstream points in the system." Waltham

rain gardens

Research has found that stream ecosystems become impaired when as little as 10 percent of the catchment is developed as impervious surface (Withers and Jarvie 2008). One stormwater reduction strategy that has gained popularity among homeowners and city planners is the construction of rain gardens. Rain gardens are just like any other landscaped gardens, except that they are planted in depressions which are strategically placed so that during rain events they will collect whatever water flows from nearby impervious surfaces (roofs, parking lots, etc.) The depressions fill, and after the rain is over, the water is absorbed back into to soil. For more information see: http://www.vacd.org/~winooski/winooski_raingarden.shtml

- The Plan provides solutions for controlling runoff and specifically mentions the goal of controlling phosphorus runoff.

construction

- The Plan uses the Vermont Green Building Network for best practices and recommendations for building codes and encourages or provides incentives for the use of Low Impact Development techniques in all new construction projects in the town.

> Encourage innovative planning, design and construction of housing that minimizes cost, energy consumption, and environmental impact. Encourage construction that complies with the Vermont energy code, Energy Star efficiency standards, LEED standards, and Vermont Residential Building Energy Standards." Ripton

- The Plan encourages the use of the Vermont Handbook for Soil Erosion and Sediment Control on Construction Sites.

siting

- The plan restricts construction in environmentally sensitive areas and on slopes due to high erosion potential.

> "Slope is a significant constraint to development; it can limit the capacity of soils for treating wastewater, as well as increase the potential for unwanted erosion and stormwater runoff. Slopes in excess of 15 percent require special consideration if they are to be developed and those in excess of 25 percent are generally unsuited for development."
>
> Orwell

development density

- The Plan promotes smart growth and cluster development, and explains the correlation between development and water quality.

> "As clean, reliable water resources are extremely valuable, all possible regulatory measures should be taken to prohibit and discourage development that would have an adverse impact on the quality of water supplies in the watershed protection district. The Town should explore the feasibility and desirability of public acquisition of land in the watershed protection district to permanently preserve the quality and availability of these resources."
>
> Starksboro

stormwater

- The Plan provides an assessment of the stormwater infrastructure in the town.

> "Our storm drainage system is not comprehensive; there are few detention ponds or treatment facilities for stormwater." Vergennes

- The Plan provides plans for mitigating the identified problems.

green streets

When stormwater runoff is not properly managed, the extra water from storm events pollutes rivers, streams and lakes and can contribute to combined sewer overflows (CSOs), causing even higher phosphorus loads to Lake Champlain. Green street strategies decrease the problems associated with stormwater runoff. By imitating natural conditions with soil and vegetation, they manage runoff at the source.

Figure 4

Figure 5

Figure 6

> "Intense development of property that results in significant changes to the natural topography of an area or large quantities of impervious surfaces (roof, roads, parking lots, etc.) can also result in flood damage to public infrastructure or neighboring properties due to stormwater runoff. Such runoff will likely result in changes to the streams such as bank erosion and channel instability, and increase water volume, velocity and pollution. Impervious surfaces reduce the amount of rainwater that is absorbed into the soil to recharge groundwater supplies. To the greatest extent feasible, development should be planned to manage stormwater in a manner that does not result in increases in the rate or volume of discharge from pre-development levels." Orwell

floodplains

- The Plan prohibits development in floodplains defined by maps from FEMA data.
- The Town has adopted Fluvial Erosion Hazard Zones and enrolled in the National Flood Insurance Program.

> "Avoid development and other encroachments – including fill, dredging, new structures, parking areas, infrastructure and utilities, and unnecessary public investments – within the mapped erosion hazard zone, and allow only forestry, agriculture, passive recreation, functionally dependent facilities, limited improvements to existing structures and facilities, and state-recommended channel management activities within this area, subject to Zoning Board review and approval." Ripton

4. roads

erosion

- The Plan calls for a reduction in roadside erosion and phosphorus runoff and discusses potential solutions.

> "Conduct ongoing efforts to ensure control of water and phosphorous runoff, thus making sure road banks are not eroding into rivers, streams, ponds, or wetlands. Direct runoff through well-vegetated areas before it reaches surface waters."

- The Plan requires that new construction and maintenance follow VTrans' Water Quality Best Management Practices.

ditches and culverts

- The Plan addresses the role of road ditches in expanding stream networks.

> "Gravel roads and driveways are a potential source of sediment to the town's surface waters. Every road or driveway can become a conduit for rainwater or snowmelt, eroding the road material and dumping it into nearby streams. Run-off and erosion from poorly constructed or maintained private roads often results in damage to the town roads they intersect with. Private roads and drives need to be constructed and maintained to prevent run-off and erosion from damaging town roads and reducing water quality in the town's water bodies. Currently, the Cornwall Road Commission must assess any new road cut for conformity with state regulations." Cornwall

- The Plan calls for the establishment of vegetated or rock-lined roadside stormwater drainage and detention areas where feasible.

> "Engage in road construction and maintenance practices that reduce erosion and sedimentation from town roads, such as reseeding ditches that have been dug out." Cornwall

vegetated and rock-lined roadside ditches

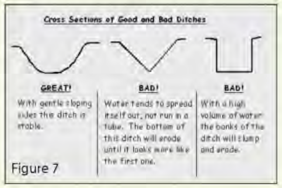

Cross Sections of Good and Bad Ditches
GREAT!
With gentle sloping sides the ditch is stable.
BAD!
Water tends to spread itself out, not run in a tube. The bottom of this ditch will erode until it looks more like the first one.
BAD!
With a high volume of water the banks of the ditch will slump and erode.

Figure 7

The establishment and maintenance of vegetated or rock-lined roadside ditches is of great importance in the effort to improve water quality in Vermont. During and after storms, poorly maintained road ditches have been found to greatly expand stream networks, which is unfortunate considering that research conducted in the Little Otter Creek watershed showed that 82% of 'bad' ditches were along roads adjacent to agricultural landuse. Lining ditches with rocks or planting vegetation can slow the flow of stormwater, prevent erosion, and reduce the phosphorous runoff into nearby surface waters.

Better Backroads

- The Plan calls for participation in the Better Backroads program.

> "The Vermont Better Backroads Manual from the Better Backroads Program recommends techniques and actions that can be used to improve the maintenance of graveled roads and drives. Salisbury's private roads and drives should be constructed and maintained to the standards described in these publications." Salisbury

salting

- The Plan addresses the problems caused by salting.

> "Wells are susceptible to natural contamination and pollutants such as leaking petroleum or industrial tanks, road salt, failing septic systems and agricultural chemicals." Ferrisburgh

- The Plan calls for a reduction or elimination in the use of salt on town roads.

5. buffers and river corridors

The Plan should:

- Strongly encourage or require the adoption of buffers and river corridors;
- Make a clear connection between establishing buffers and protecting water quality
- Explain the financial incentives offered by Act 110.

> "The Plan identifies a Riverine Habitat and River Corridor Overlay Area that will promote the health, safety and welfare of the citizens of Lincoln by allowing the river to move within its corridor; mitigate increases in downstream river erosion resulting from development; minimize property loss and damage due to river erosion; and limit land uses and development that may pose a danger to health and safety. The Area will also protect water quality, aquatic and terrestrial habitat, and maintain riverine wetlands." Lincoln

Act 110

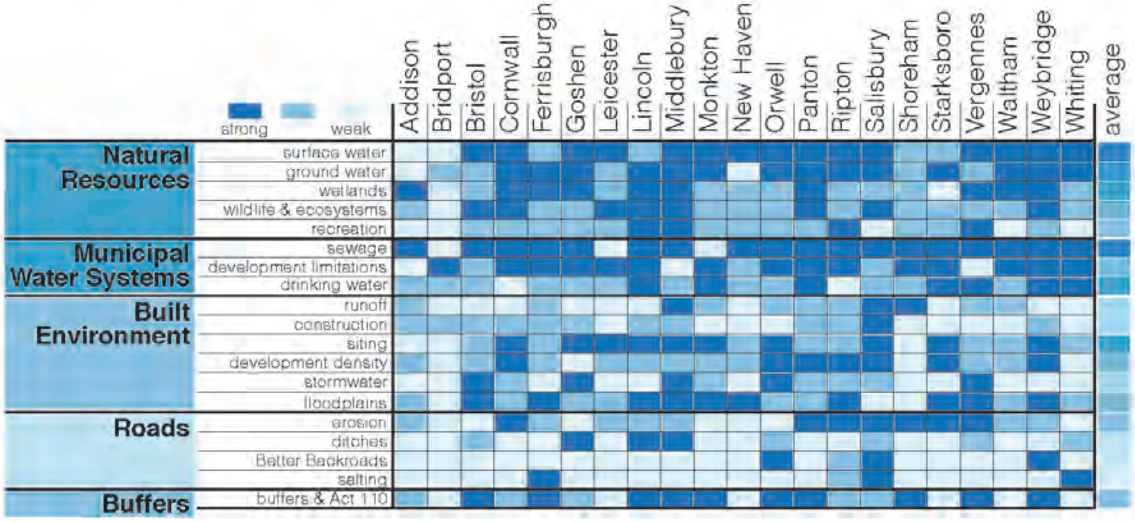
Act 110 was passed in Vermont in May 2010 and presents great opportunities for town planners to improve water quality in their communities. The Act's primary goal is to establish a river corridor management program and a shoreland management program which focus on the creation of vegetated riparian buffer zones. These simple strips of vegetated land have been shown to significantly decrease phosphorus levels in adjacent surface waters when stragtegically placed along shorelines. The Act requires that the secretary of administration, after consultation with relevant state agencies, offer incentives to municipalities to encourage adoption and implementation of zoning bylaws that protect shorelands, river corridors and buffers.

With Act 110, Vermont's legislators hope to encourage the adoption of their Best Managment Practices and other water quality recommendations by offering financial incentives to willing towns, but admits that "If Vermont is to prevent continual degradation of lake habitat and water quality, mandatory statewide protection such as a lakeshore buffer regulation should be seriously considered" (Act 110, River Corridor Managment and Lake Shoreland Managment Programs, Report to the General Assembly, p. 4).

compiling the RESULTS

Through the compilation of water quality policy for all 21 towns in Addison County, we discovered various trends. A town would often reference nearby towns and their Town Plans, suggesting that some cross-pollination exists between towns. This can lead to both sections of stronger policy and others of heavy omission.

After compiling the data, we completed two forms of analysis. Our first graphic compares our five categories: Natural Resources, Municipal Water Systems, Built Environment, Roads and Buffers. Our second rates all 21 towns based on water quality policy.



observing trends

The graphic above indicates strong to weak policy in our five categories for all 21 towns. By creating a table we are able to notice blocks of strong policy and blocks of weak policy. For example, the predominantly light color of the 'roads' section indicates that this category tended to have weak language. The darker coloration of the Natural Resources indicates that there already exists a framework for strong water quality langauge in these sections. This is likely because Natural Resources is a section required by the Addison County Regional Planning Commission for all Town Plans.

Another way of reading this graphic is by observing trends by town. Some towns are found to have relatively weak language throughout, while some towns are almost entirely dark, representing overall strong water policy language.

It is important to note that these differentiated catagories are not strict catagories in the Town Plan. We extracted policy and language throughout and created these catagories based on our results. We would like to emphasize the importance that all parts of the Town Plan are written in concert with goals of strict water policy in mind.

Town Plan Water Quality Policy

Ranking.

Town	Score
Bridport	42%
Addison	54%
New Haven	56%
Leicester	58%
Shoreham	61%
Waltham	63%
Whiting	63%
Starksboro	67%
Monkton	68%
Bristol	70%
Cornwall	72%
Ferrisburgh	72%
Goshen	72%
Orwell	77%
Panton	77%
Vergennes	77%
Lincoln	79%
Ripton	79%
Weybridge	81%
Middlebury	82%
Salisbury	82%

Our second graphic ranks the 21 towns in Addison County. They are organized from towns in need of the most improvement to the least improvement. We scored each town on their water quality content and language, by assigning a nominal value to the 'strong', 'medium' or 'weak' rating. The town average was 70%. Salisbury had the strongest policy scoring an 83%. Bridport had the lowest score, mostly due to its high number of omissions.